PHYSIOLOGY
AND HYGIENE
BLOUNT

G. H. THOMPSON

PHYSIOLOGY AND HYGIENE

A TEXT-BOOK AND MANUAL

FOR

HIGH SCHOOLS

BY

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PREFACE

This book is written for pupils between twelve and sixteen years of age. With the minimum quantity of laboratory work called for in the text, the course can be finished in ten weeks. If a class can spend a half year on the subject, the text will be adequate for a recitation guide. The work should be supplemented by the study of a variety of animals to illustrate the several physiological processes in organisms less complex than the human. For example, the short sketch of respiration on page 108 should be expanded to several days' laboratory work. The comparative study of the blood systems of the animal groups, and of the skins and their outgrowths, of the nervous systems, etc., would be equally profitable.

The book does not convey all the knowledge the pupil should acquire on the subject, neither is it intended to take the place of the teacher. It is designed, rather, to aid the capable teacher and guide the diligent and painstaking worker. Many of the lessons need to be worked out in class with the use of material provided by the teacher.

No special laboratory room is needed, though it would be convenient. A list of the supplies required will be found on a following page. The resourceful teacher will supplement the list by various illustrative materials as he finds opportunity. The absolutely indispensable supplies can be obtained at a very slight expense.

The practical exercises woven in with the descriptive

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text have been worked out by the author in many years of ninth grade teaching, and have proved thoroughly practicable. The pupil should keep a note book, and write in it the answers to the questions which occur in each lesson as well as the supplementary work which may be given by the teacher. Most of the questions asked can be answered easily if the directions in the text are followed. The few difficult questions are asked because they are questions that ought to arise at the places they are inserted. Why not learn in our school days that there are baffling problems for whose solution we shall have to wait a long time?

A resume of the first chapter is given at its close, *as a sample*. The pupil should write in his note book such a resume of each chapter.

A few of the illustrations are original; the others have been gleaned from various sources, most of them redrawn and simplified. The author was assisted in preparing the illustrations by one of his former pupils, Reuben Schick, and by Mary Elida Porter.

The author is also under obligation to the teachers of the Chicago high schools who have read portions of the manuscript and made valuable suggestions,—especially to James H. Smith and Mary Bockes Pardee. Charles Louis Mix, M. D., and Winfield S. Hall, M. D., professors in the Northwestern University Medical School, and Dr. and Mrs. William Healy, also, have made helpful criticisms. Special acknowledgment is also made to Dr. Anna E. Blount, who has collaborated with the author through the entire work, has pruned out inaccuracies, supplemented deficiencies, and written a number of pages.

THE AUTHOR.

Chicago, August, 1914.

SUPPLIES

The materials needed for the work outlined in the following chapters are here listed in sufficient quantities for a class of twenty-four pupils. For larger classes it would be well to increase the quantity of each item. Several divisions doing the same work in one day could use much of the same material and so keep down the proportional expense. The material exhausted in using is estimated between three and four dollars for the class. Exclusive of the skeleton, the permanent equipment should not cost more than ten dollars. Nearly all the apparatus could be borrowed as needed from other science laboratories. Some of the observational work is to be done at home. The household articles used are not included in this list:

CHAPTER 2. Two dozen glass tumblers..........$ .72

Two dozen small dishes...................... .72

CHAPTER 3. An articulated skeleton can be had for from $30 to $40. The work can be done and the material passed around the class more conveniently if separate bones are used. A set would cost $15 or $20 and up, but incomplete sets could be got for less. If human bones are not accessible, the bones of a cat, a dog, a pig, etc., will serve.

Fresh bones and joints, from the market........ .20

Hydrochloric acid .... .05

CHAPTER 4. A pound of fibrous meat cut into one inch pieces .... .15

CHAPTER 5. Half a dozen calf heads............ .50

Half a dozen sheep necks.................... .50

Half dozen prepared stained sections of spinal cord, to be made in the Biological Laboratory.

CHAPTER 6. A dozen sheep plucks............. .60

A dozen or more seekers. These may be made by the pupils from strips of bamboo ⅛ inch wide, tipped with sealing wax, or charred at the end.

CHAPTER 7. One dozen sheep lungs............ .25

One dozen ½ inch test tubes, each with a hole in the bottom .... .25

CHAPTER 8. Reagents for food tests—nitric acid, ammonia, iodine in potassium iodide solution, Haynes' solution, sulfuric acid............... .75

One dozen test tubes ½ inch................... .25

Bunsen burners or alcohol lamps.
Food samples—brought by the pupils.

CHAPTER 10. Two dozen small mirrors......... .40

Extracted teeth—as many as an obliging dentist will give.

CHAPTER 11. Two dozen hand magnifiers....... 5.00

Pieces of torn leather.
One dozen ink pads........................ 1.50
One ounce of ether, chloroform or alcohol...... .10

CHAPTER 13. A. Mirrors listed in Chapter 10....

E. One dozen pairs of compasses........... 1.80

CONTENTS

DAVID di MICHELANGIOLO
Accedemia di Belle Arti

ARTEMIS of VERSAILLES
Louvre, Paris

PHYSIOLOGY AND HYGIENE

THE PURPOSE OF THE COURSE

The body is the means by which we accomplish all we do, intellectual as well as physical. Consider how perfectly the two figures on the preceding page are adapted to express,—the one, strength, endurance, dignity; the other, grace, freedom, aspiration. We should all be pleased to have bodies as well adapted as these for the work and the play of life. Such bodies do not often come by chance. Nature supplies the possibility; we must work out the actuality. In the ardor of preparation for an athletic contest, a boy will train persistently and conscientiously to bring his body to its best condition. Life is full of conflicts that try the mettle of any boy or girl. There is always the demand for a strong body to fight the battles. This book aims to help you to develop your bodies so that they may be capable of expressing the courage and tenacity, the dignity and grace of your life.

If you were entering upon a long journey, lasting for many years, and were obliged to make that

journey in one machine, let us say an automobile, you would need to consider carefully that machine. You would need to study its construction, to know every part in its relation to every other part, to understand the origin of the power and how it is applied. You should be able to detect any flaws in the machine or in its working and, if necessary, to correct the troubles.

Life is such a journey. You are given one mechanism, your body, with which to make this journey. You must, therefore, study it well, drive it carefully, and learn to stop and "overhaul the machine" when it seems out of order. Sometimes for good ends you may speed it up; at other times you must go slowly and put on all power to climb a steep hill, but you must never put the priceless thing to a needless risk. You should know the materials of this body-engine, the structure and use of every part, and how the parts all work together for one common purpose. You should know the source of your power, and how that power is applied, set free to drive the engine. You should know the accidents that are most likely to occur, that you may guard against them; the imperfections of the body-engine, that you may relieve the weak places from strain. You should watch for wear and attend to repairs in time, for though this is a self-repairing machine it must be given opportunity for repair. When any part is

worn past its own power of repair it cannot be replaced, its function is lost, and to this extent the work of the whole machine is impaired.

Anatomy. The study of the construction of the human machine is called anatomy. By its derivation the word means "to cut up," since the body must be dissected to get at its interior details. We shall learn these details through the study of parts of some lower animals and through pictures.

Physiology. Each part of the body has a use, a function. The study of the functions of the parts and of the way all work together for the common good is called physiology.

Hygiene. We study the body to the practical end that we may keep it well; in other words, that we may run our machine to the best advantage. We are in good health when every part of the body is doing its work well. It is of vital importance that we learn what wholesome things to do, and what harmful things to avoid, in order to maintain this condition. But there is another way in which the body is unlike a machine; it is endowed with the power of growth and development. Year by year, from babyhood to manhood or womanhood, you should increase the power of the machine. You must, therefore, consider how best to *develop* your body. The study of the laws of health, the development and care of the body, is called *hygiene*.

Life unit—the cell. If we put under the micro-
scope a little of the sediment from the bottom, or
of the scum from the surface of some pond, we
may find in it minute plants or animals whose
essential structure is represented in this diagram.
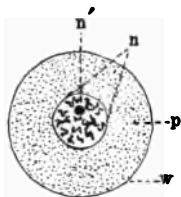
FIG. 1. Diagram
of a typical cell.
w—wall, p—proto-
plasm, n—nucleus,
n'—nucleolus.

(Fig. 1.)   At the outside is a thin
membrane called the cell-wall.
Within is a fluid called proto-
plasm, most of which is thin and
watery. A denser part of the pro-
toplasm, the nucleus, apparently
more active and much more com-
plicated in structure, appears as a
round or oval spot. The cell is the
simplest form of life. Protoplasm
is alive, and it is the only living substance known.

Tissue. The simplest forms of plants and ani-
mals are composed of single cells or of a few cells
joined together. The larger and higher forms are
composed of many millions of cells of different
sizes and shapes and having different functions.
Millions of cells of one kind are grouped together
to form the liver, cells of another kind form the
brain, of still another kind form muscle, and so on.
Cells may be joined together tightly, forming a
compact mass, or they may be separated by inter-
cellular substances which serve a useful purpose.
For example, among the bone cells there is a large
amount of intercellular stony material. A tendon is com-

posed almost entire-
ly of intercellular
threads. Such
threads or fibers are
found in nearly all
parts of the body,
forming a frame-
work for the softer
parts. (Fig. 2.) A
tissue is a group of
cells of a certain
kind or of cells and
intercellular sub-
stances set apart to
do a certain work.
For example, there
is liver tissue, com-
posed of liver cells
shaped and arranged
in a certain way and
having a special
function; muscle tis-
sue, recognized by
cells of a distinctive
form and function;
brain tissue, marked
by peculiar nerve
cells; and so on for
all the parts.

FIG. 2. Fibrous intercellular ma-
terial. The white fibers (a) appear
as simple threads; among them are
seen the cells which produce them.
The yellow elastic fibers (b) are
much larger. How else do they differ
from the white? The cells which
produce them are not shown. The
elastic fibers are found in a few
stretching ligaments and in the walls
of the arteries. The white fibers are
in most ligaments, in the tendons,
and, in fact, in nearly every tissue.

Lymph. Besides the various kinds of tissue, the body contains fluids. In the minute spaces between the cells and between fibers and in the large spaces between internal parts of the body lies a watery fluid called lymph. This fluid holds in solution any of the body substances it can dissolve.
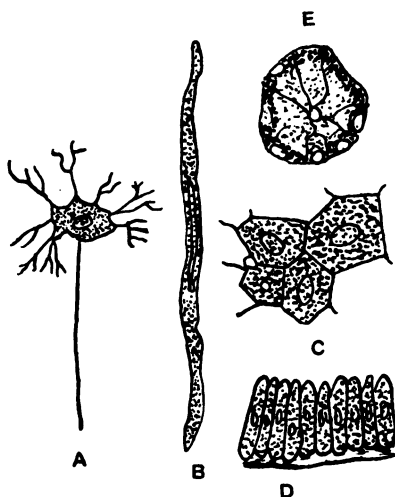
Fig. 3. Various forms of cells, much magnified. A, a nerve cell from the spinal cord, magnified 100 times. B, a muscle cell from the wall of an artery, magnified 350 times. C, cells from the surface of a serous membrane. D, section from the mucous membrane of the intestine. E, section across a tube of the salivary gland.

The body is, then, a thoroughly porous mass of cells and intercellular substances, the spaces are filled with a watery fluid, and all is covered with a practically watertight skin.

Cell form. The form of each special kind of cell is adapted to its work. Study Part A of Fig. 3, representing a nerve cell from the spinal cord. This nerve cell has to receive and send out nerve currents. The outgoing current goes over the single large fiber, the incoming current comes through the root-like projections.

1. Does the cell seem to be able to receive currents from only one, or from several sources?

2. About what is the diameter of the main part of the cell, if the figure is in length one hundred times the natural size?

3. What is the length of the muscle cell, if drawing B multiplies it three hundred fifty times?

4. How is the shape of the cell adapted to its work of contracting?

5. The cells in C are thin; describe their shape.

6. Would any other form of cell cover a surface so compactly?

7. In part D the cells are viewed from the side. Their top surface forms the surface-lining of the intestine. They are fastened to the membrane at the base. Would you infer from their length that they have any important function other than to make a tight lining?

9. How are the cells of the salivary gland arranged with reference to the small tube which carries away the saliva they produce?

Protoplasm. The substance known as protoplasm resembles the raw white of egg. It is watery and colorless. Chemically it is composed of four chief elements—carbon, hydrogen, oxygen, and nitrogen, and of a number of other elements in very small quantities, among which are sulphur, phosphorus, and potassium. Protoplasm is the living substance. Since it is to be the chief object of our study, we need to understand what is meant by a living substance, and that is much the same as knowing what protoplasm can do.

1. Protoplasm can assimilate food; that is, it can take into itself certain food substances and make them over into material like itself. This production of new protoplasm is involved in all growth and repair. There is no other known way in which protoplasm can be produced.

2. The cell, which is the unit of protoplasm, can divide so that the number of cells increases. The nucleus, by a complicated process, divides into two nuclei, a line of separation forms between them, and there are two cells instead of one. (Fig. 4.) Increase in the number or size of cells is growth in animals and plants.
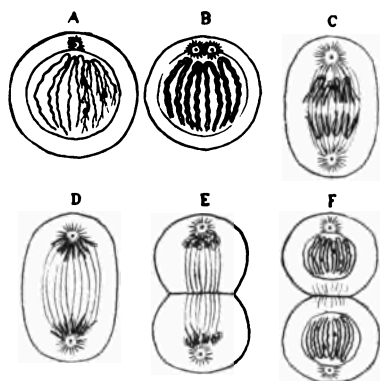
FIG. 4. Diagram to show the changes a nucleus undergoes in cell division. The nucleus is shown occupying more of the cell than it usually does.

3. Protoplasm can move. In plant cells it can be seen circulating in tiny streams about the cell; in muscle cells it contracts and expands, the long cells becoming alternately shorter and thicker, then longer and thinner.

4. Protoplasm is irritable; that is, it acts in response to a stimulus. If you touch a one-cell

animal, he draws away; if a food particle comes in contact with him, he advances and surrounds it. While all the protoplasm of the higher animals responds to some extent to stimuli, the nervous system is most highly irritable. The common way of distinguishing live protoplasm from dead is to apply a stimulus and see if the protoplasm responds.

5. Protoplasm breaks down, or undergoes chemical change, when it acts. In the process of assimilation, protoplasm is built up into a very complex but unstable substance. You remember it contains carbon, hydrogen, oxygen, etc. When the protoplasm acts (secretes, contracts) some of the oxygen combines with the hydrogen, forming water (H_2O), and other oxygen combines with the carbon, forming carbon dioxide (CO_2). Thus more simple and stable substances are formed by the tearing down of a complex, unstable substance. This is a process essentially like the burning that takes place in a furnace, only slower. It is called oxidation, because the hydrogen and carbon combine with oxygen. The fuel in the furnace is composed mostly of carbon (C). The draft admits the air containing oxygen (O) and in the heat of the fire the fuel is broken up, and each atom of carbon combines with two atoms of oxygen, forming the gas carbon dioxide (CO_2). These chemical changes in the protoplasm, as in the furnace, de-

velop electricity, heat, motion, and other mani-
festations of energy. In the complex protoplasm
there is much stored-up energy which is freed upon
its breaking down. In fact, the disintegration of
the protoplasm is largely for the purpose of trans-
forming its energy into the various forms of work
—secretion, heat, and motion. The resemblance
to the furnace is very close. The food taken into
the protoplasm corresponds to the fuel of the fur-
nace. The burning of the fuel is for the purpose
of transforming its stored-up energy into the mo-
tion of the engine. So the oxidation of the food
in the protoplasm transforms its energy into the
activities of the cell.

Energy. We have spoken of protoplasm as an
energy producer. Energy is power to do work, to
produce changes in the condition of a body, such
as moving, producing an electrical or chemical
change, melting ice, evaporating water, etc. There
is a law of nature called *"conservation of energy."*
This means that energy cannot be destroyed or
produced. It is transformed from one kind of
manifestation to another. Thus heat energy is
transformed into motion in the steam engine, and
chemical energy is transformed into electric energy
in the battery—with no loss in quantity during the
transformation. So true is this that, knowing the
amount of energy liberated by burning a pound of
coal, we can figure the amount of coal and oxygen

necessary to produce a given amount of electricity, heat, or mechanical work. The flood of rays streaming from the sun to the earth supply us with nearly all the energy we have. The rays, that seem so simple, manifest themselves in various ways. To the eye they are light; to the skin they are warmth; on the photographic plate they make pictures; within the green leaf laboratory, the protoplasm of the plant, they build up sugar or starch, the fundamental substances on which all plant and animal life rests. From the air the carbon dioxide (CO_2) enters the leaf; from the ground comes the water (H_2O). The energy of the sun's rays combines these two substances into sugar and sets free some oxygen.

$$\left.\begin{array}{c}\text{12 molecules of}\\\text{carbon dioxide}\end{array}\right\} + \left\{\begin{array}{c}\text{11 molecules}\\\text{of water}\end{array}\right. = \left\{\begin{array}{c}\text{1 molecule}\\\text{of sugar}\end{array}\right. + \left\{\begin{array}{c}\text{12 molecules}\\\text{of oxygen}\end{array}\right.$$

$$12\ CO_2 \quad + \quad 11\ H_2O \quad = \quad C_{12}H_{22}O_{11} \quad + \quad 12\ O_2$$
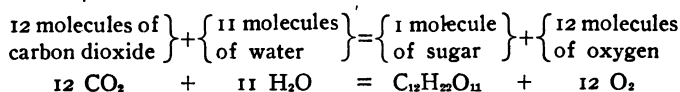
The energy of the ray is stored up in the sugar, or more accurately stated, in the affinity of the sugar for oxygen. If the sugar should combine with oxygen, oxidize, or burn, CO_2 and H_2O would be produced, and the stored-up energy would appear as heat.

$$\left.\begin{array}{c}\text{1 molecule}\\\text{of sugar}\end{array}\right\} + \left\{\begin{array}{c}\text{12 molecules}\\\text{of oxygen}\end{array}\right. = \left\{\begin{array}{c}\text{12 molecules}\\\text{of carbon dioxide}\end{array}\right\} + \left\{\begin{array}{c}\text{11 molecules}\\\text{of water}\end{array}\right.$$

$$C_{12}H_{22}O_{11} \quad + \quad 12\ O_2 \quad = \quad 12\ CO_2 \quad + \quad 11\ H_2O$$
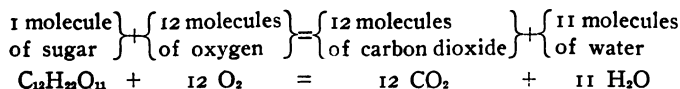
For the upbuilding of the highly complex proto-

plasm a great deal of energy is used, all of which appears again as heat or motion or in some other form when the protoplasm breaks down. We say that energy is stored up in sugar, in, fat, in coal, in protoplasm because all the energy that went into their upbuilding can be utilized again as heat or light or motion when the food or fuel is oxidized. We must not lose sight of the fact that the body is an engine, a living engine to be sure, but one that uses the ordinary forms of energy, transforming them for its purposes to produce muscular activity and heat and to elaborate chemical substances.

The needs of protoplasm. Protoplasm can sustain its life only under certain conditions. Consider the protoplasm of a cell of the brain or of a muscle. The muscle contracts or the brain cell sends out a nerve current; some of the protoplasm is torn down to simpler compounds, waste products. Let the action be repeated. The protoplasm is soon worn out by the oxidation process. That it may remain alive, capable of carrying on its characteristic life activities, the loss must be restored. The protoplasm builds itself up again from the food and oxygen brought to it. Therefore the needs of protoplasm are (first) food and (second) oxygen.

1. To maintain its life protoplasm must be supplied with *food*.

2. For activity protoplasm must have oxygen.

3. As a result of the tearing down of the proto-plasm there is present in it carbon dioxide and other products of oxidation. These waste products are injurious to the protoplasm and must be re-moved. It is the blood and lymph, circulating through the body, that bring the food and oxygen to the cells and remove the products of oxidation.

4. If the hand is held in boiling water, or if the skin is severely frozen, its life is destroyed. To preserve life the temperature of protoplasm must be kept within certain limits. What the limits are differs with different protoplasm. Some plants and small animals remain for weeks at a temperature considerably below freezing, and some can endure even boiling for a short time. The cells of the human skin can endure the temperature of hot water (perhaps 115 degrees) and for a short time a freezing temperature (32 degrees), but if the interior of the body reaches a temperature as high as 110 degrees or as low as 95 degrees death is likely to occur. The mouth temperature is on the average 98.6 degrees, and in health does not depart more than a degree from this.

5. Protoplasm needs to be kept moist. Active protoplasm requires a good deal of water and is easily killed by drying. Yet seeds in maturing lose most of their water and may remain dry in a rest-ing condition for years. They can resume their

activity in sprouting only after they have absorbed
a large quantity of water.

These five conditions must be maintained con-
tinually for the protoplasm in all parts of the body.
Except for propagation of its own kind, the entire
physiological activity of every living animal, the
structure and work of every organ of the body
has for its end the maintenance of these five condi-
tions—together with one other, protection against
injury. Our study must make clear how all parts
of the body work together to accomplish these
ends. Each lesson should add something to the
solution of this problem, and you have not finished
the study of any organ or process until you under-
stand the part it plays in this co-operative work.

SUMMARY

A sound and able body is needed for such life as we
all desire. Life is a journey; the body is the engine that
carries us through. We must learn to manage it well.

Anatomy treats of the structure of the body, physiology
of its functions, and hygiene of its care—the practical
end of our study.

The unit of structure of the body is the cell, com-
posed of protoplasm, with usually a nucleus and often
a wall.

Tissues are groups of many cells of the same kind,
having a special function, together with characteristic
intercellular substances.

The minute spaces in tissues and the larger spaces
between organs are filled with a circulating fluid called

lymph. The skin is a water-tight covering to keep this fluid from escaping from the body.

Cells have many forms, each adapted to the special work it has to do.

Protoplasm is composed of four chief elements, carbon, hydrogen, oxygen and nitrogen, with several minor elements.

Protoplasm can assimilate, multiply, move, respond to stimulus, and liberate energy in breaking down.

The energy manifested on the earth comes from the sun. Energy cannot be produced or destroyed, but may pass from one form of manifestation to another. The fundamental life activities are the transformations of energy involved in the upbuilding and down-breaking of protoplasm.

Protoplasm needs food, oxygen, removal of waste, temperature kept within certain limits, moisture and protection. All parts of the body co-operate to provide these necessities.

MICRO-ORGANISMS

At the outset of our work we must consider some groups of small plants and animals that are very influential for good or for evil in the life of man. Since they affect nearly all parts of the body, it is important that we understand them at the beginning of our study. They are called bacteria germs, micro-organisms, or microbes, and are commonly single cells, so exceedingly small that hundreds of them could be held on the point of a pin. Single germs can be seen only with a microscope of high power.

Bacteria. The more common vegetable germs are bacteria and they are so small that no interior structure can be seen. They appear to be specks of protoplasm encased in a wall of such material as that which forms wood and paper. Under favorable conditions bacteria increase in number very rapidly by simply dividing. In a warm, moist food material a single germ could, in the course of twenty-four hours, multiply to over 16,000,000. Some kinds of bacteria are able to move by means of tiny threads of protoplasm projecting from

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their surface, but most varieties move only as they
are carried by wind, water, animals, and like means.

1. What appearance have bacteria when moderately
magnified?
2. What shapes do they show when very highly mag-
nified?
3. What are their diameters in Fig. 5?
4. Compute the size of the germs themselves.
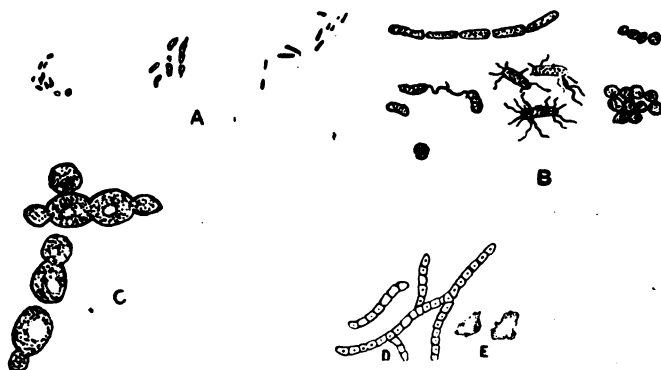
FIG. 5. Micro-organisms. A, bacteria magnified 500 or 600
times; B, bacteria magnified about 2000 times; C, yeast; D, a
ring-worm parasite; E, plasmodia of malaria.

Other microbes. There are a few kinds of veg-
etable germs other than bacteria which produce
infectious diseases; for example, a variety of yeast
and some mould-like forms. But the diseases they
cause are not common. Several very common dis-
eases, however, are produced by microscopic one-
cell animals called plasmodia. These germs are
specks of bare protoplasm, usually larger than

bacteria. They have the power of drawing in or
pushing out any part of their minute bodies and so
changing their shape.

Microbe life conditions. All of these microbes
require for their life favorable conditions of food,
oxygen, moisture, and temperature mentioned in
the preceding chapter. Some are able to resist a
temperature almost equal to boiling, while freezing
does not kill them. They sometimes go into a sort
of resting stage and form about themselves a tight
shell. This drying, however, does not destroy
them. They are later blown about, and some finally
drop into a moist substance which serves as food.
Here they soften and resume growth. They differ
a great deal in the substances they require for food.
Most of them would flourish in the food that nour-
ishes us, while many live in surroundings that
would seem to us most unwholesome, as in the
bodies of decaying plants and animals.

How studied. Germs are so small that it is
impossible to distinguish the different kinds merely
by their appearance under the microscope; all their
life peculiarities must be studied. They are put in
small glass dishes in the laboratory, supplied with
food, and kept at a certain temperature. Gelatine
containing beef broth is a food commonly used.
As the germs grow they produce spots in the jelly;
some liquefy the jelly as they grow, others do not;
some grow rapidly, some slowly; some have strik-

ing color, as red or yellow. By these various peculiarities, as well as by their appearance under the microscope, they are recognized.

For the cultivation of a few kinds of germs found in the water or air, a boiled potato is easier to pre- pare than the beef broth gelatine. After washing the potato clean, boil it for about a half hour. When it is cool, cut it into a few thick slices with a sterile knife (one that has been boiled, held in a flame, or rinsed in alcohol or some other anti- septic solution). On one slice of potato put a few drops of water from the tap; on another a few drops of milk; touch one to the floor; touch an- other to your hand; let another stand in the air for fifteen minutes. As soon as each piece is exposed, place it in a saucer on a piece of blotting paper wet with boiled water and cover it with a clean tumbler. Stand it in a warm place and look at it every day for a week or two, to see the growth of the colonies of mould and bacteria. Most disease germs will not grow on potato. Some resist all attempts at cultivation outside the human body.

Products. As the germs grow they produce cer- tain substances. For instance, yeast in a solution containing sugar produces carbon dioxide and alco- hol; bacteria in meat produce the poisons of tainted meat; others in milk produce the acid of sour milk. Most, if not all, disease germs produce

a poison—each kind of germ its own special poison
—called toxin.

Beneficial microbes. There are hundreds of
kinds of microbes and, though many produce poi-
sons or cause diseases by growing in the body, a
much larger number are not only harmless but
very beneficial. In fact, we could not live without
them. Soil is made fit for plants by the microbes
in it. The ground would soon become covered
with leaves, sticks, tree trunks, and the bodies of
dead animals if they did not decay, through the
work of bacteria and other minute organisms. The
ripening of cream for butter, the maturing of
cheese, the rising of bread, and the fermenting of
liquors are accomplished by various bacteria.

Guarding against microbes. We have learned
several ways of protecting ourselves against harm-
ful germs. Meats, vegetables, and fruits are pre-
served against decay by cold storage, for the bac-
teria that cause decay increase very slowly, if at
all, at the freezing temperature. A very high tem-
perature kills germs, so we boil drinking water
which we suspect of containing disease germs. If
meats, vegetables, and fruits are well boiled, and
sealed in air-tight cans while still boiling hot, they
will keep an indefinite time. Canning is a scientific
process. One woman has "better luck" than her
neighbor because she has her jars clean (free from
germs), puts the fruit in boiling hot, and immedi-

ately screws the tops on tight. It is all a matter of leaving no live germs in the jars and giving none a chance to get in.

Substances that contain no live germs are said to be sterile or aseptic. Make the following experiment in sterilization: Into several test tubes put some food substance, milk, broth, fruit juice, or nutrient gelatine, to the depth of about two inches. Plug each tube with a snug-fitting but not too tight stopper of absorbent cotton. Stand the tubes in a dish of water and boil for at least a half hour. When the tubes are cool, remove the cotton plugs from half of them and let them stand open in the room. Keep the remaining tubes closed. Observe the tubes from day to day and explain the changes you see. Do germs go through a plug of dry cotton?

Antiseptics. Substances that kill or check the growth of germs are called antiseptics. The most efficient antiseptics are strong poisons, which must be handled with great care. Corrosive sublimate (mercury bichloride) and carbolic acid are used in dilute solution in washing the surgeon's hands and instruments and in cleansing wounds. Formalin and the fumes of burning sulphur are employed in disinfecting rooms and clothing used by a patient suffering from an infectious disease. Boracic acid is used in washing a tender surface such as the eye or a wound. Borax preparations are used also in

preserving meat, and it is claimed that they do not injure the wholesomeness of the food. Salt, used in large quantities, is an antiseptic, and is therefore used in preserving meats, fish, and pickles. Smoke also preserves meat because it contains the antiseptic creosote and because it leaves the surface of the meat dry and firm and thus impervious to germs.

Prepare some slices of potato for germ culture as directed on page 27. After they have been exposed to the germs, spray them thoroughly with an antiseptic—formalin or alcohol—and cover them with clean tumblers. In test tubes containing milk, broth, or fruit juice put a few drops of carbolic acid or formalin or a few grains of mercury bichloride and shake thoroughly. Stand the tubes in a warm room. Do bacteria and moulds grow in these poisoned foods, as they did in the foods not treated with antiseptics?

Microbes and disease. It is in relation to diseases that microbes are of most interest to us here. That they are the direct cause of many infectious diseases has been proved beyond any question. Certain germs have been found in the bodies of the sick, studied under the microscope, cultivated in the laboratory, introduced into the bodies of healthy animals, and have produced the same disease as that which afflicted the person from whom they were taken. We get the infectious disease by

taking into our bodies the disease microbes, and we get it in no other way. It has not been proved that all infectious diseases are caused by minute plant or animal parasites—germs, but it is quite probable. The difficulty of proof lies in the fact that some germs can hardly be separated from others, in whose company they occur, and cultivated in the laboratory. It is supposed that each infectious disease either has its own special germ, which produces only that one disease (as, for instance, diphtheria), or it may be caused by any one of several germs (as in meningitis), or by several kinds of germs co-operating to produce it. Several kinds of bacteria are sometimes found together in boils and carbuncles.

Whenever pus occurs it is caused by microbes, sometimes one kind, sometimes another, sometimes several kinds together. Pus is a fluid filled with germs and white blood corpuscles, usually creamy, sometimes bluish, or, if stained with blood, pink.

In the pages that follow we shall have frequent occasion to refer to the relations of germs to various parts of the body. Two entire chapters (XIV and XVI) are given to the discussion of diseases caused by germs and to the methods of treating and preventing them.

NOTE.—The pupil should write a summary of this and of each following chapter, observing the form of the summary given at the end of Chapter I.

BONES AND JOINTS

In this chapter you will learn why the human body needs bones, how their structure is adapted to their use, and how they maintain their own life; why the body needs joints, what their essential parts are, the function of each part, and how the different kinds are suited to different uses.

Uses of bones. There are some animals of moderate size that have no bones and no hard parts that serve the purpose of bones. They are slow of movement and are buoyed up only by the water in which they live.

1. From a study of the figure of the human skeleton (page 33) name several bones whose function is the support of soft organs.

2. Name others which protect parts of the body.

3. What bones are especially used in movement?

4. What is the most important characteristic of their shape?

5. What service can the arm, because of its bones, perform better than an organ such as the elephant's trunk?

The general skeleton. If a set of human bones cannot be had, the skeleton of a cat, a dog, or other mammal may be used in answering the following
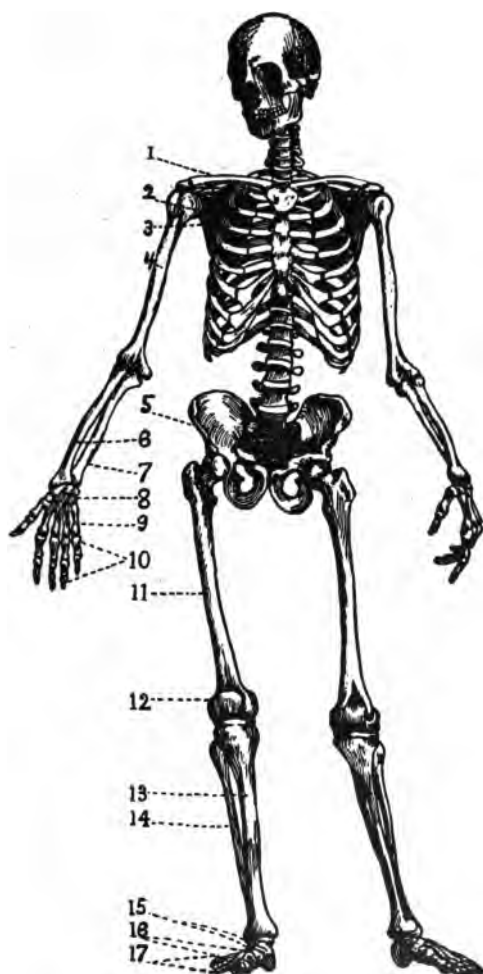
1. Clavicle or collar bone.

2. Rib.

3. Scapula or shoulder blade.

4. Humerus.

5. Pelvis or hip bones.

6. Radius.

7. Ulna.

8. Carpal or wrist bones.

9. Metacarpal or hand bones.

10. Phalanges or finger bones.

11. Femur or thigh.

12. Patella or knee cap.

13. Tibia.

14. Fibula.

15. Tarsal or ankle bones.

16. Metatarsal or foot bones.

17. Phalanges or toe bones.

Fig. 6.

FIRST
CERVICAL
OR ATLAS
SECOND
CERVICAL
OR AXIS

FIRST
THORACIC

FIRST
LUMBAR

SACRUM

COCCYX

questions. See also the figure of the skeleton, page 33.

1. What is the main axis of the skeleton? What is one section of this called?

2. Of how many vertebrae is it composed? (See Fig. 7.)

3. Which of the vertebrae have ribs attached to them?

4. Why should the lower vertebrae be so much stronger than the upper?

5. What two bones make the joint that allows the free rotation of the head?

6. How many ribs are there on each side?

7. To what are the upper seven ribs attached on the front or ventral side?

8. Explain the difference in the ventral attachment

Fig. 7. The spinal column from the left side. The white space between two vertebrae is cartilage. At its dorsal border (right) is an opening into the spinal canal. The shaded round spot on the centrum and on the lateral process of each thoracic vertebra is the place where the rib joins.

of the eighth, ninth and tenth ribs; of the eleventh and twelfth.

9. Observe the shoulder girdle and the pelvic girdle, with their dependent limbs. Which girdle is firmer? Why need it be?

10. Write in one column the names of the bones of the arm and hand, and in a parallel column those of the bones of the leg and foot, placing the names of like bones opposite each other, and underscoring those which have no corresponding bones.

STUDY OF A LONG BONE

1. How do the extremities of a long bone differ in diameter from the shaft?

2. In the longitudinal section, how do the extremities differ in structure from the shaft?

3. Why could not the shaft just as well have the same spongy structure as the ends? Why could not the ends just as well have the dense structure of the shaft?

4. The rough protuberances and depressions are for the attachment of muscles and tendons; where are they most numerous?

5. Give as many reasons as you can why the ends need to be larger than the shaft?

6. In a section of fresh bone, what occupies the middle of the shaft?

7. Why is it better, from a mechanical standpoint, to have the shaft hollow instead of solid?

8. Where do you find openings for blood vessels and nerves to enter the bone?

9. On the outer surface of a fresh bone, loosen a small part of the periosteum (covering membrane) and describe it.

10. Make a sketch of a longitudinal section and name the parts.

Study of a Short, Irregular Bone

1. In the section of a short bone is the bone composed of spongy or of compact tissue.

2. Where do you find openings for blood vessels and nerves?

3. Where are the places for muscle or tendon attachments?

4. Describe the surface of the bone where it moves on another bone.

Study of the Shoulder Blade—Scapula

1. Are your own shoulder blades firmly or loosely attached to your ribs?

2. What uses has the large crest on the dorsal side of the bone?

3. Describe the surface where the arm bone (humerus) joins the scapula.

Study of the Hip or Pelvic Bones

1. Why is the pelvis shaped like a bowl?

2. Is it closed or open at the bottom?

3. Why is the dorsal part so much stronger than the ventral part?

4. The bone upon which the vertebral column rests is called the sacrum. It is formed by the union of how many vertebra-like bones?

5. Of what use is the deep socket on each side of the pelvis?

6. Where do you see rough surfaces or projections for the attachment of muscles?

Study of a Rib

1. Describe the general shape of a rib.

2. Can you bend your ribs? What is the advantage of this condition?

3. How does the ventral part differ in form from the dorsal part?

4. How many smooth spots, for joining other bones, do you find on a rib?

Study of a Vertebra

1. Notice the two general parts—the body or centrum and the dorsal arch. A projection from a bone is called a process.

2. From which part of the vertebra do the dorsal and the lateral processes project? Large muscles lie lengthwise of the body along these processes.

3. Of what use are the anterior and posterior processes from the dorsal arch?

4. What part of the vertebra lies ventral to the large canal holding the spinal cord? What part lies dorsal?

5. Where is there a place for the spinal nerves to leave the canal?

6. Make a sketch of a vertebra, end view, and name the parts.

Study of the Skull

(a) The Cranium (brain case).

1. Sketch about one-half inch of a suture, the joining of two bones.

2. Describe the three layers seen in a section of the roof bones.

3. How do the floor bones differ from the roof bones in thickness?

4. Where is the opening for the spinal cord?

5. Where does the first vertebra join the skull?

6. Where are the small openings through which blood vessels and nerves pass?

(b) The Facial Bones.

7. Is the upper jaw firmly or movably fastened to the skull?

8. Does the lower jaw hinge to the skull before or behind the ear?

9. Where are the rough places and projections to which are attached the muscles that close the jaw?

10. Where are the openings through which nerves from the lower part of the face enter the jaw bone? Where do these nerves and those from the lower teeth come out of the bone?

11. By what means are the teeth held firmly in place?

12. What kind of partition separates the two nasal cavities?

13. By what sort of bone is the inner surface of the nose cavity enlarged? In life this bone is covered by a membrane.

Composition of bone. Put a piece of dry bone into a bottle of dilute hydrochloric acid. What do you see rising through the water from the surface of the bone? This is the gas, carbon dioxide. It is produced by the action of acid on the limestone (calcium carbonate) in the bone. About two-thirds of the bone is stony matter, calcium carbonate and calcium phosphate. Describe a bone that has been soaking in acid several days, until all the stony substance has been dissolved. The material that remains is animal substance. It may

be taken out of the bone by burning, but the burning changes the stony material also. The burnt bone is more fragile than it would be if the animal substance were removed without affecting the mineral. The stony and the animal substance of the bone are so intimately mingled that even the smallest particles contain both elements, therefore the shape is unchanged when all of either substance is removed.

1. The bone owes its stiffness to which substance?
2. To which substance does it owe its toughness?
3. What difference in composition makes a child's bones more flexible than those of an adult?

Minute structure. You must understand that bone tissue is alive, and that every part of it must be supplied by a fluid from the blood which brings food and oxygen and carries away waste. Figure 8 shows a microscopic section of dense bone, such as knife handles are made of. Around what as a center do the concentric layers of bone lie? What is the diameter of these canals which contain the blood vessels? From them the fluid must ooze through the canaliculi to the protoplasm, which lies in the small irregular cavities. Between these cavities which contain the bone cells, penetrated by the canaliculi, lie intermingled the gristly and the stony substances of the bone.

Periosteum. Covering the bone everywhere except at the joints is a tough membrane called peri-

osteum. If the bone is broken or a piece taken out, the cells of the periosteum produce material to repair the injury. From these new cells grow out and soon change into bone tissue.
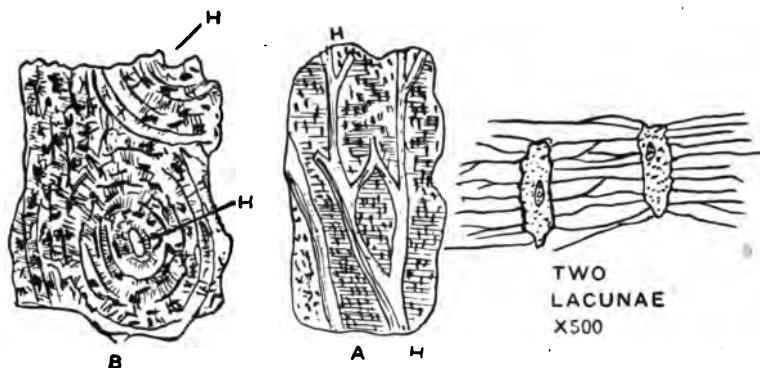
Fig. 8. A, a longitudinal section of bone. B, a transverse section of bone. Both are magnified about 75 times. H, Haversian canals. The black specks are lacunae. Each of the two shown more highly magnified is filled with a cell. The canaliculi connect the cells.

Germ disease in bone. Bones as well as other parts of the body suffer from germ diseases. What is there in bones which can serve as food for microbes? If a bone or a considerable part of a bone is destroyed by germs, deformity is likely to result. Tuberculosis often causes hunchback, and occasionally affects bones in other parts of the body. Some other contagious diseases also affect bones. If a disease is checked when the bone is only partially destroyed the periosteum and the bone cells set about repairing the damage, but

they often produce a superabundance of bone ma-
terial and make a large lump on the bone and this
appears as a deformity.

Fracture. When the bone of an adult is frac-
tured, the brittle, stony substance, and also the
tough animal substance, are broken in a rough sur-

FIG. 9. A, "green stick" fracture of the radius. B, a fracture
of the tibia. The contraction of the leg muscles would have
what effect on the length of the broken leg?

face, and the cells of the bone and of the periosteum
are torn. In the healing process perhaps the bone
cells and surely the periosteum cells adjacent to
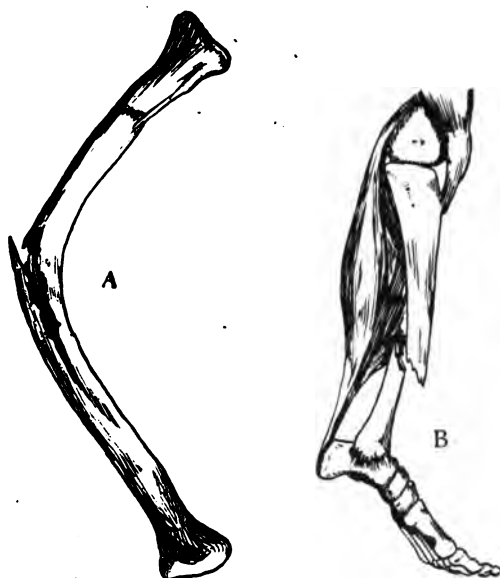the injury multiply and fill the break. Gradually
strong bone material replaces these soft cells, fas-

tens together the broken ends, and makes the bone as strong as ever—perhaps stronger than before, for the new growth often covers the break with a large callus. This lump does no injury on the shaft of a long bone, but at a joint it may seriously obstruct freedom of motion.

It is especially important that the broken bone be kept quiet during the time of "knitting." If the broken ends are moved on one another before the filling material has hardened, the union is likely to be imperfect, the bone crooked, or the callus very large. Sometimes people use a broken limb as soon as the swelling and the pain have disappeared, and then blame the physician if the break does not heal perfectly.

Sometimes breaks in children's bones are called "green stick" fractures, because the bone does not snap off like a dry twig, but bends and cracks like a green shoot. The small amount of stony substance breaks, while the tough animal material bends and often holds the bone together. This break is quickly healed, but the bone should be carefully guarded against strain until it has recovered its full strength.

Rachitis, Rickets. One of the most common causes of deformity and under-development of bones is deficient nourishment of small children. Although the child may get a sufficient quantity of food, he may not get the lime salts necessary

for stiffening the bone. This lack of nutrition results in a disease called rickets, one of the symptoms of which is weak and crooked bones. The leg bones become bowed under the weight of the body, though not all bow legs are due to rickets. The arms and skull and other bones are affected. The disease is easily cured if the child is given a proper diet before the bones become hardened in their distorted form. The teeth are composed of the same substances as are the bones, and often show by their easy crumbling the deficiency of the diet.

Effect of alcohol on the bones. Some parents, not understanding the evil they are doing, allow their little children to partake of the alcoholic drinks they are themselves using. This often impairs the nutrition of the child and causes rickets. A moderate use of alcohol in adults has no noticeable effect on the bones, but in confirmed inebriates the bones suffer with the remainder of the body. A break heals only with great difficulty, and sometimes the fracture of a bone precipitates an attack of delirium tremens.

Joints. Where two bones come together they make a joint. In some cases the bones are firmly fastened together, and in other cases they move one on the other. Find in the skeleton several instances of the first case. In the fixed joints the bones are clearly separate in childhood, but in old

age they are so firmly grown together that they appear as one. Why should not the bones of the cranium be firmly grown together in childhood?

Structure of a joint. In a dry specimen observe whether the bearing surface of the bone at a movable joint is smooth or rough. This surface in the live bone is covered with cartilage instead of with the periosteum which encases the remainder of the bone.

1. Describe the cartilage in a fresh specimen—its color, thickness, etc. Is it firm or yielding?

2. What is the color of the ligaments binding one bone to another?

3. Are they firm or soft?

4. Can they be stretched like rubber?

5. Has the dry bone where the ligaments fasten a smooth, or a rough surface?

6. The joint cavity is the inside of a closed sack called the synovium. The outside of the synovium grows so tightly to the cartilage and ligaments that it can scarcely be distinguished from them. As the joint moves all the rubbing surface is inside of the synovial sack. What sort of a surface is it?

7. Describe the synovial fluid which lubricates the joint—its color, feel, etc.

Movements and Forms of Joints

1. Study the skeleton, Fig. 6, and determine in which bone is the socket, and in which the ball of the hip joint.

2. Stand and move your own leg at the hip; in what direction can a ball and socket joint bend?

3. Find another joint that has the same free movement and seems to be a ball and socket joint.

4. In what direction can the knee joint move?

5. Find another joint that has a hinge form.

6. Move the jaw from side to side. This is a sliding or gliding joint.

7. What would lead you to think that the wrist and ankle may also glide?

8. In a dry skeleton observe how the first vertebra is joined to the second. This is a pivot joint. It allows what movement of the head?

9. Name four kinds of joints studied in this paragraph.

Dislocations and sprains. When the movement of a bone at a joint is forced, the bone may slip out of place, so that the muscles can no longer bend the joint. This is called a dislocation. If the ligaments are very slack dislocations occur easily, but the dislocated bone may slip back into place just as readily. Frequently dislocation tears some of the fibers of the ligaments, and healing requires several weeks. After the dislocated bone has been brought into place, the joint is bandaged to hold it secure. After a few days the joint is bent back and forth carefully and exercised every day to prevent stiffness.

If, however, the movement is so violent as to tear some fibers of the ligament, and yet not displace the bones, the accident is a sprain. A sprain may also involve the bruising of the cartilage at the end of the bone. It is a very painful injury,

slow to heal, and should be treated with great care.
The swelling of a sprain is caused by the lymph
and blood flowing into and often filling the joint
cavity and surrounding tissue.   Gentle rubbing
helps to reduce it.   Hot dressings are used to re-
lieve the pain.   If no infection occurs the sprain
usually heals without stiffness.   In case of infec-
tion the injury should have the attention of a
surgeon.

The feet. The bones and joints of the feet suffer
severely from unhygienic shoes.   Shoes that are
too large rub against the feet and cause a thick-
ening of the epidermis which results in corns.   But
injuries to the bones and joints come from shoes
that are too tight.   The toes especially suffer.   If
the shoe is too short, the second toe is bent under
at the end, its second joint is humped up and a
corn often develops.   In a short time this results
in a deformity called a hammer toe.   Narrow shoes
are likely to crowd one toe, especially the great toe,
over its neighbor.   This extreme outward bending
of the great toe makes the joint prominent.   The
joint then bears the pressure of the shoe, and a
bunion, an unnatural growth of fibrous tissue and
of bone, is the result.

High heels throw the weight of the body forward
upon the toes, crowding them into too narrow
quarters.   This results in their deformity, and
sometimes in "flat foot."

The bones of the foot and ankle are arranged in the form of an arch, with the heel at one end and the ball of the foot at the other. The tibia, supporting the weight of the body, rests on the top of the arch. The arch is elastic, and gives at each step, making a spring which decreases the jar on the body. A weak arch sometimes loses its springiness and settles down. This is called "flat foot." It causes pain in the foot and leg while standing, and produces an awkward gait.

Most injuries to the feet can be remedied. Proper bandages, supports, and exercises will do much for a flat foot. The skin over a bunion can be cut open and the bony growth chiseled off. Crooked toes can be straightened. Corns can be softened and removed. But the sensible thing to do is to take such good care of the feet that such injuries and deformities never come.

The shoe should fit just right—neither so tight as to bind nor so loose as to chafe. The lacing over the instep should be snug so that the toes do not push against the end of the shoe. The toes particularly should have plenty of room, both at the sides and end. The heels should be low; rubber makes a comfortable, easy heel. If a shoe that is large enough presses uncomfortably on some part of the foot, have a second pair and change daily. Each pair will fit somewhat differently, and each joint, muscle, or spot of skin made uncom-

fortable by one pair will probably be rested by the other.

Walking is one of the most convenient and healthful forms of recreation, but tender and deformed feet discourage exercise in the fresh air. If the feet get tired, bathe and rub them daily or oftener. Watch for corns and ingrowing toenails, and attend to them as soon as they appear. A great deal of nerve-racking pain may be avoided by caring for the feet.

Each pupil should make his own summary of this and subsequent chapters.

CHAPTER IV

MUSCLES

In this chapter you will study how muscles do their work, how differently the many kinds of muscles act, and how you can preserve their power and increase their efficiency.

Function. All motions of the body and of its organs are produced by muscles, and this work is their main but not their only function. The muscles fastened to the skeleton are composed of long fibers which become shorter and thicker in contraction, thus pulling on the bones to which they are fastened. Their force is always exerted in pulling, never in pushing. Even when we make a thrust movement, as in striking forward with the fist, the muscles employed pull on a set of levers—the arm bones. When the muscles relax they exert no force.

Limb muscles. While the left arm hangs relaxed, feel with the fingers of the right hand the muscles of the upper arm. With a string or a tape, measure the circumference of the arm. Bend the arm at the elbow vigorously; now feel the contracted muscles and measure the circumference of the arm.

49

1. Is the contracted muscle softer or harder, longer or shorter, thicker or thinner than the relaxed muscle?

2. Bend the fingers of the left hand vigorously several times; with the right hand feel for the contracted muscles. Where are they?

3. Where can you feel the tendons (cords) through which these muscles make their pull on the fingers?

4. While the fingers are closed, bend the wrist forward. Where are the muscles that control the bending?

5. Bend the wrist backward; where are the muscles that control this motion?

6. Why should the muscles be so far away from the parts moved?

7. Where are the muscles (biceps) that bend the arm at the elbow?

8. Where are the muscles (triceps) that straighten the arm at the elbow? If the hand is moved against a resisting object the muscular contraction will be more vigorous and so more. evident.

9. As you sit, lift the toes from the floor, letting the foot rest on the heel. Where are the muscles that do the work?

10. Raise the heel from the floor, resting the foot on the toes. Where are the muscles that do this work ?

Amount of force. The bones of the limbs are levers through which the muscles work. Figure 10 illustrates the mechanical principle at the elbow joint. The tendon of the biceps is fastened to the forearm at p, the hand is at w, and the humerus at f. The distance represented by pf is about an inch and that by wf is about fifteen inches. Therefore to raise a weight of 10 lbs. in the hand, the

muscles would have to contract with a force of
150 lbs. The triceps tendon is fastened at p', about
¾ inch from f. To straighten the arm against a
resistance of 10 lbs. at the hand, the triceps would
have to contract with a force of 200 lbs.
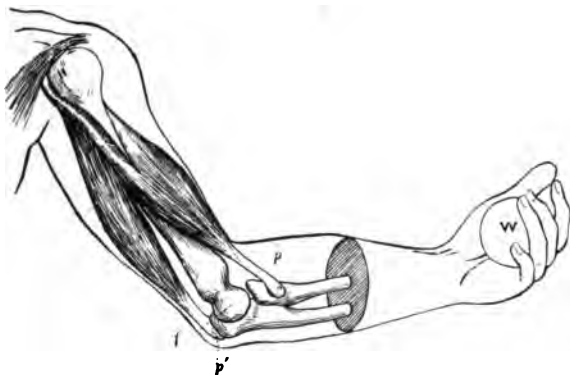
FIG. 10. To illustrate the leverage of the forearm. p—inser-
tion of the biceps, p'—insertion of the triceps, f—the end of the
femur, w—the weight to be lifted.

The arrangement of the bones and muscles at
the other limb joints is similar to that at the elbow.
These muscles always work at a tremendous disad-
vantage of power. To compensate for this, the
muscle contracting through a fraction of an inch
can produce a motion of several inches at the end
of the bone it moves.

1. A man of ordinary strength can bend the elbow with
a weight of 40 lbs. in the hand. This would require a
biceps contraction of how many pounds?

2. Draw a straight line 15 inches long, and letter the
ends F and W. One inch from F make a dot one-half

ınch above the line. From the point F draw through this dot another line equal to the first and letter its free end W'. The distance WW' is the distance the hand moves when the biceps contracts one-half inch.

3. Make a diagram to represent the movement of the hand when the triceps contract.

Position of limb muscles. Is the position of the leg muscles such that the swing of the leg in walking carries it backward and forward much or little? Compare with the horse. Which animal has legs better suited for running? How would the efficiency of the hand be changed if the muscles that work the fingers were in the hand instead of in the forearm?

Head and trunk muscles.

1. Rest the forehead against the hand and, while the hand resists, try to move the head forward. With the other hand feel the contracted muscles and determine in what part of the neck they are located.

2. Try to move the head backward against resistance. Where are the contracting muscles located?

3. Set the teeth together and bite hard. Where can you feel the muscles contract?

4. Using a mirror, where can you see them?

5. Find the muscles used in moving the shoulders forward and downward; in shrugging the shoulders; in raising the arm.

6. Lean lazily forward against your desk and feel the muscles in the small of the back. While your hand is pressing your back, bring the body to an erect position. Where do you feel the muscle contract?

1, occipito-frontalis
2, temporal
3, masseter
4, orbicularis oris
5, platysma myoides
6, sterno-mastoid
7, deltold
8, biceps
9, triceps
10, brachio-radialis

11, pectoralis major
12, serratus anterior
13, rectus abdominis
14, obliquus externus
15, sartorius
16, rectus femoris
18, tibialis anterior
19, extensor digi-
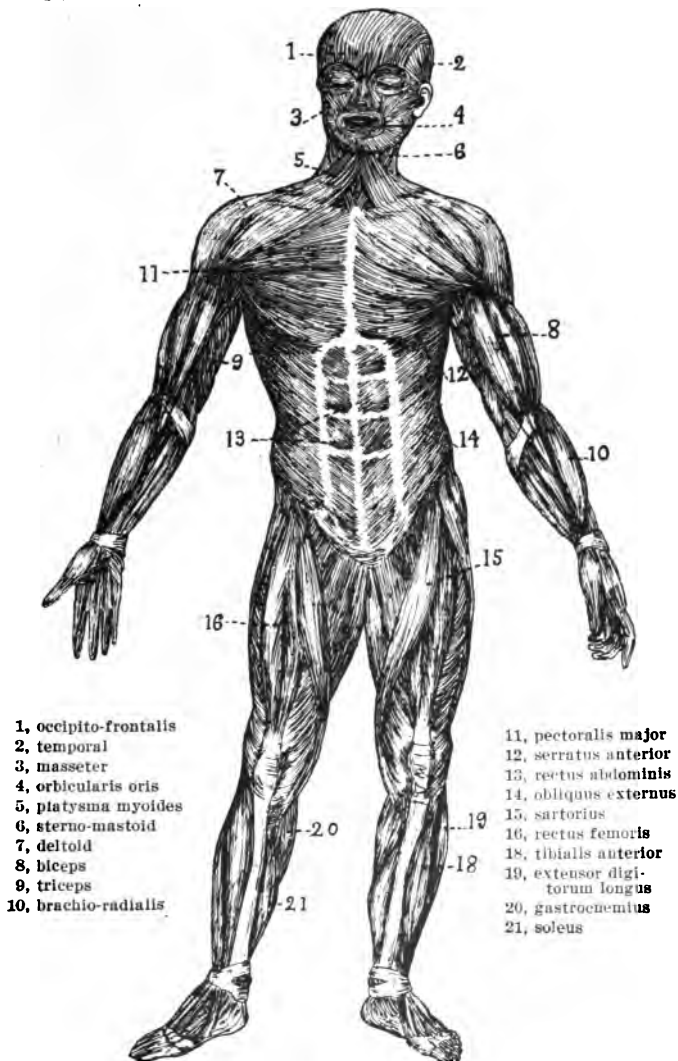   torum longus
20, gastrocnemius
21, soleus

FIG. 11. The superficial muscles of the body, appearing when the skin is removed. Some of the deeper muscles are larger and stronger than those here shown. Make the named muscles contract in your own body, and see what work each does.

7. From lying flat on the back, rise to a sitting posture. Where can you feel muscles contract?

Examination of muscle. Examine a piece of stringy meat with a little fat in it.

1. What three colors of tissue do you see in the specimen? Which is muscle? Which is fat? Which is connective tissue?

2. Pick some of the muscle to pieces with a pin or with your finger nail. About how large are the smallest fibers into which the muscle splits?

3. Compare the thickness and strength of the sheath (perimysium) which envelops the large piece of muscle with that which covers the small piece.

4. Pull the tendonous connective tissue. Does it stretch like rubber? If it were other than it is why would it be unsuited to the work it has to do?

5. Sketch a bit of the cross section of the muscle to show the arrangement of the little bundles.

Classes of muscles. Microscopically the muscle you have examined has the structure shown in Figure 12A. It is called a striated muscle, from the Latin word *stria,* meaning furrow. Observe the location of the nuclei. Around each fiber is a delicate membrane and around each group of fibers a stronger membrane. The common muscles of the body are striated, but in the wall of the stomach and intestine, in the wall of the veins and arteries, in the iris of the eye, and some other places we find non-striated or smooth muscles. Observe the shape and size of the cells shown in

Figure 12C. This is non-striated or smooth muscle.

A third class of muscle is found only in the heart. See Figure 12B. Has this muscle striae? Muscles of the first class are usually large and bunchy, and are fastened to bones. They contract all at once, and are partly or completely under the control of the will. Non-striated muscles are in sheets, around cavities. They contract one part after another, rather slowly, and they are usually involuntary. To get an illustration of the action of a smooth muscle, place your neighbor so that he will face a bright

A'   A

FIG. 12. Muscle fibers. A, portion of a striated fiber; the entire fiber may be an inch or more long, and ¼₀₀ of an inch wide.

A' shows a more highly magnified fiber, with the ending of the nerve which stimulates it. Are the nuclei more or less numerous at the nerve ending than at other places?

light. Hold your hand an inch or two before his eyes, so as to shade them, yet so that you can see them well. Watch the pupils change as you remove your hand. The motion is produced by muscles in the iris.

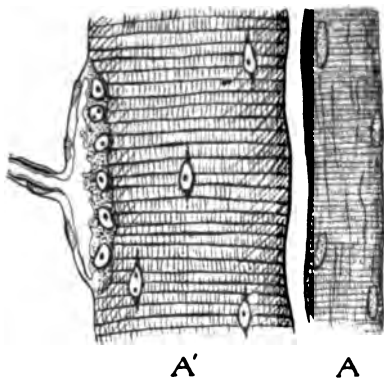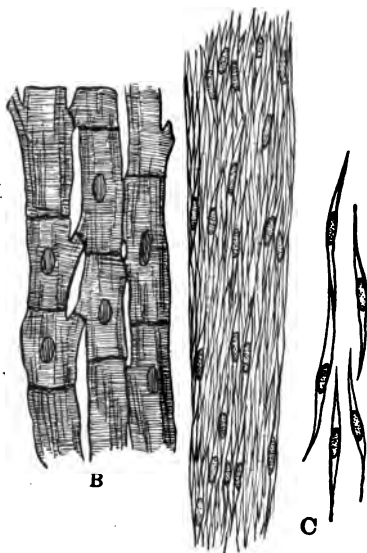**Nerve control.** The common striated muscles

are altogether under the control of the nerve system. They lie relaxed until they receive a stimulus from a nerve, then they contract, gently or vigorously, according to the stimulus. The skill that comes with practice is the result of the development of the control of the nerve system rather than of the muscles themselves. If two men have muscles of the same size, one may be much stronger because his nerve battery is more powerful. Athletic endurance trials are tests of the nerves that control the muscles.

The smooth muscles and the heart muscles are largely, but perhaps not completely, under nerve control.

B, fibers of heart muscle, magnified about as A. Are the fibers longer, or shorter, than common striated muscle fibers? Are they wider, or narrower? Do they branch? The empty spaces between cells shown in the figure result from pulling the cells apart; in life the cells are tight together.

C, smooth or non-striated fibers. Each cell has a single nucleus. How different from in B do these cells join? They are about $\frac{1}{500}$ of an inch long, and $\frac{1}{4000}$ of an inch wide.

Wear. In muscular contraction, nerve cells and

muscles both are oxidized, forming carbon dioxide, water, and nitrogenous waste. A good blood circulation is needed to remove the products of oxidation and to bring food and oxygen for rebuilding the used protoplasm.

Heat. You are familiar with the fact that muscular activity produces heat. In warm weather the amount of work we can do is restricted by the rise in the temperature of the body. We must not produce heat faster than we can get rid of it. In cold weather, however, the heat of muscular contraction is a very welcome addition to the temperature of the body. In fact, if the temperature gets too low the muscles are set in motion to produce heat by shivering.

Need of exercise. Commonly we do not understand how necessary to our health is muscular activity, and we frequently neglect taking adequate exercise. The human race has developed under conditions which have demanded strenuous physical exertion. To get food and to escape his enemies, to meet the demands of the chase and of war, man became fleet of foot, supple of body, and strong of arm. The great majority of mankind still earn their livelihood by physical labor. The large muscles, which most men require in their daily occupation, need activity, and if those of us who are cooped up in offices, schools or shops, with no call for large muscular activities, neglect to find some daily

means of exercise, we must pay the penalty. We probably do not know all the ways in which muscular activity benefits the body. We do understand some of the details of our need of exercise, and we shall now consider them.

Muscular development. For the growth of the muscles themselves it is necessary that they be active. Boys and girls generally are disposed to physical activity, but some young folk as well as adults do not realize how necessary to growth is activity. Normal young persons have within them a force that drives them to move about. It is impossible for a healthy child to keep still. The young of all the common animals have the play instinct. Puppies and kittens tumble one another about, and colts and kids race and jump, insuring the exercise necessary for their muscular growth and for the development of the nerves that control the muscles. This principle is a condition of healthy vigor throughout life.

Exercise and respiration. Active muscles require a large quantity of oxygen, and produce much carbon dioxide. The respiration must consequently be rapid to bring in the oxygen and take out the carbon dioxide. It is almost impossible to develop a strong chest with good lung capacity if one does not take vigorous exercise. The welfare of the whole body, as well as of the muscles, is promoted by the improved respiration.

1. Compare the rate of your breathing when at rest and when physically active.

2. In which condition do you fill your lungs most completely?

Exercise and circulation. It is necessary for the proper growth of the heart muscles and for the strengthening of the organ to meet the severe demands made upon it, that it be frequently exercised vigorously. This is best done by the vigorous activity of the whole body. The contraction of a muscle squeezes out of it the sluggish lymph and the blood that is slowly moving through the blood tubes, and makes room for fresh blood. `Thus the active muscle cells are bathed with a quickly-moving, fresh fluid, and the circulation of the entire body is invigorated by the exercise.

Exercise and heat. We have learned that the chief source of heat in the body is the oxidation that occurs in muscular contraction. On a cold day a person of vigorous muscular development in light clothes is kept comfortable by the heat produced within his body, while his thin-muscled neighbor shivers in his heavy wraps. We say that our fingers and toes, our ears and nose get cold because our blood circulation is not brisk enough. The way to have a circulation suited to our needs is to train the heart and blood vessels by exercise to respond to the demand made upon them.

Effects of muscular activity. The beneficial ef-

fects of muscular activity are more far-reaching
than the influences on growth, respiration, circula-
tion and temperature. The parts of the body are
so intimately connected that whatever influences
one part, influences all. The whole body responds
to the improved tone of well-exercised muscles.
The mind becomes more alert and vigorous. These
far-reaching effects may be the result of good res-
piration or circulation, or both. They are at least
the result of suitable exercise.

Play. The spirit in which we exercise is very
important. To produce the best results, the activ-
ity should not be dull work, but should in part be
play, or done in the spirit of play. Play is usually
a free and much varied activity, bringing into
action many muscles; while work is often a dull
repetition of restricted motions. The enthusiasm
with which we enter into play is a very important
element of its value. If we could engage in our
physical work with the same enthusiasm that we
carry into play, we should get much more work
done and find it less exhausting.

Intensity. Exercise should be vigorous. A boy
or girl in poor health or unaccustomed to exercise
may find a little walk sufficient, but for one in his
normal condition the activity should call for strong
contraction of the muscles, and should be con-
tinued until he is well tired—fatigued, but not ex-
hausted. When the muscle cell breaks down more

rapidly than it is rebuilt by the food and oxygen
of the blood, it becomes exhausted and rapidly
loses its power to work. Exhaustion is less rapid
when the blood has a good food supply, but it
finally comes if the activity is too long continued.
No muscle should be held in continuous vigorous
contraction for more than a few seconds at a time.
The ideal exercise involves a great variety of move-
ments, some rapid some slow, some gentle, some
strenuous, with periods of rest interspersed. Think
of several forms of work and of play that fulfil
these requirements.

Serious injury may result from too strenuous ac-
tivity, especially in growing youth. The heart is
overworked, stretched, weakened for life in a very
large percentage of the athletes who engage in
football, boat and marathon contests. It is just as
important not to over-do as not to under-do the
vigor of exercise.

Food. Careful experiments in measuring the
force of a muscle's contraction show that the first
of several repeated motions is the strongest. After
a few contractions the force diminishes very rap-
idly. Rest and food, however, restore the vigor of
the muscle. In a general way we understand that
we cannot work unless we eat, but we do not
usually appreciate how quickly a muscle responds
to abundance or scarcity of food in the blood. The
omission of a meal has been found to decrease the

force of muscle contraction about one-half. The practice of going without breakfast may be helpful to some diseased stomachs, but the body needs food for the work of the day, and the ordinary boy or girl should prepare for the day by taking a substantial breakfast.

Alcohol and narcotics. The general effect of alcohol, in small or large quantities, is to decrease the force of muscular contraction. It is true that the effect of a small dose of alcohol on the muscle is, under certain conditions, stimulating; that is, the muscles contract more quickly and with greater force. But this effect soon passes, and the muscles have less strength than they had before. The habitual use of alcohol slowly weakens the muscles. They do not assimilate food nor do they grow so well when alcohol is present. The stronger the liquor and the more it is used, the worse the effect. In extreme cases some of the muscle cells degenerate into fat. People who use alcohol and tobacco to excess have very imperfect control of their muscles. Muscular contraction is deranged chiefly by the effect of the drugs on the motor nerve centers.

THE NERVE SYSTEM

The nerve function. There are some tiny single-celled animals which are composed of a continuous mass of protoplasm. If one side of such an animal is touched, all the protoplasm contracts, drawing the animal away from danger. There must be some way in which the protoplasm touched takes cognizance of the touch and communicates its discovery to all the protoplasm of the animal. Somewhat larger animals composed of hundreds of cells, yet still very small, respond to a touch in the same way. In them the protoplasm that feels the touch must send its message through other cells to all parts of the body. Any cell of these tiny creatures seems to have the power of receiving impressions from the outside world and of communicating them to other parts of the body. This power is necessary for putting the animal into relation with the world around him, for enabling him to get food and escape danger, and also for correlating one part of the body with another. This function, which we may call irritability, is possessed by all the protoplasm in the lowest animals. You will learn in this chapter how the same need of relation to the

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outside world and of correlation within is more fully met by the highly developed nerve system of man.

The neuron. The unit of structure in the nerve

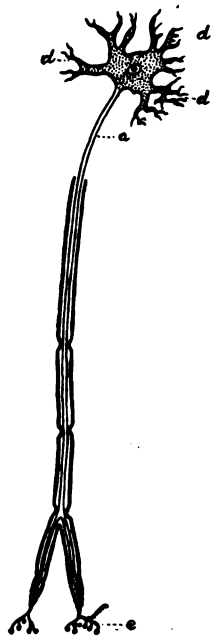FIG. 13. Diagrammatic representation of a neuron. d, dendrites; a, axon, which is covered most of its length with a sheath; e, end of nerve in muscle, etc.
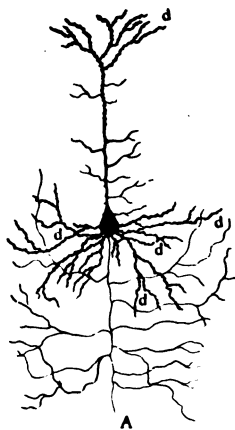
FIG. 14. A highly developed neuron, magnified 20 or 30 times. Only the beginning of the axon is shown. d, dendrites; A, axon.

system is the neuron. It consists of a large cell, 1/200 of an inch in diameter or smaller, and the projections growing out from it. One is shown in

Figure 14. Compare it with the diagram in Figure
13. The protoplasm projections, called dendrites
(tree-form), are for receiving currents from other
neurons. Observe the number on a single cell.
The neuraxon or nerve fiber is a prolongation of
the cell protoplasm which enables it to send cur-
rents to different parts of the body. Each cell has
but one nerve fiber, sometimes only a fraction of
an inch in length, and sometimes two or three feet.
Its diameter is very slight. Along its course
through the body it is, in most cases, covered by a
tube composed of cells encased in a thin membrane.
The fiber gives off no branches where it is covered,
but near the ends, where the covering is absent, it
may branch, sometimes abundantly. The nerve cells
are grouped together in various parts of the body, as
in the brain and spinal cord, and each group of cells
is called a ganglion.

The nerve. A nerve is a bundle of cell projec-
tions, neuraxons, few or many in number, together
with connective tissue and blood-vessels. It is like
a telegraph cable of many wires bound together,
each going to its own destination and insulated
from its neighbors. The nerves give off many
branches, but these are merely fibers separating
from the main group. The fibers themselves do
not branch. Figure 15 shows a cross section of a
nerve. At the outside are strengthening connective
tissue and blood vessels. Each fiber appears as a

small circle in whose center is the axis or active part, the outgrowth from the cell.

Method of action. The following example will illustrate the way in which the nerve system acts: A fly alights on your hand. From a touch organ in the skin beneath him a current is sent over a nerve fiber or neuron whose cell is located in a spinal ganglion. See Figures 16 and 21. This neuron passes the current on to a central cell in the

FIG. 15. Cross section of a nerve, magnified. The membranous connective tissue at the outside is represented quite diagrammatically. The nerve fibers are in bundles, between which are connective tissue and blood vessels. The nerve is represented shrunk away from its covering, which in life it fills.

spinal cord. The receiving cell undergoes a chemical change; some of its protoplasm breaking down into less complex substances, carbon dioxide, water and nitrogenous waste. It sends a current out to a motor cell which in turn sends a current to a muscle. The muscle contracts and produces a motion to drive away the offending insect.

This is a nerve action reduced to simple terms. In this action there are involved, first, a neuron reaching from the touch organ to the spinal cord.

with its cell located in the spinal ganglion; second, one or more central neurons which receive the current and communicate with a third, the neuron carrying the current out to the muscle. We should not expect to find the process actually so simple. Instead of a single current over one fiber, there are several currents over several fibers going from the skin to the spinal cord. The receiving cells may send currents through a complicated network of correlating neurons which finally stimulate the motor cells to discharge into the muscles. The muscles which produce any considerable motion would require for their contraction the stimulus of a whole battery of nerve cells.
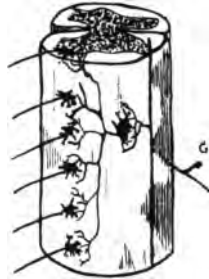
FIG. 16. A diagrammatic representation of a portion of the spinal cord. The size of the nerves and cells is greatly exaggerated. G—a cell of the ·spinal ganglion; there is one central cell, and at the left are six motor cells.

Reflex, voluntary, and automatic action. An action like that just described, in which a sense organ sends a current to the spinal cord or to some minor ganglion that immediately stimulates the muscle, is called a reflex action. It is the quickest and most economical response we can get to an outside stimulus. In some reflexes, especially in lower animals, it is thought that sensory nerve fibers communicate directly with motor cell dendrites without the in-

tervention of central neurons. In contrast with this is, first, the voluntary action, in which the receiving cells communicate with the brain which issues the motor current; and, second, the automatic action, which is unlike the reflex in that it arises from an internal condition instead of from an external stimulus.
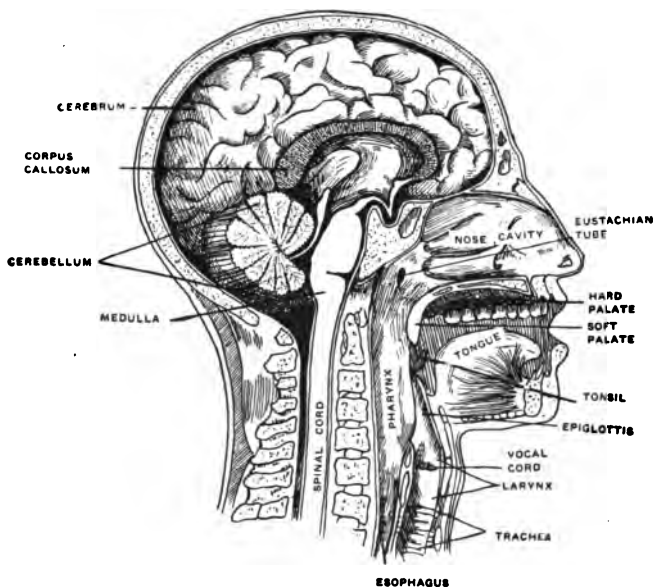

FIG. 17. Left half of the head and neck, median section. Notice the situation and chief parts of the brain.

Be prepared to tell of examples of each of the three kinds of action.

The nerve current. What the nerve current is, which goes along the nerve from sense organ to

cell, from one cell to another, and from cell to muscle or gland, no one seems to know. It is something like an electric current, but while the electric current is practically instantaneous over a wire, the nerve current travels through the nerve at the rate of about ninety feet per second. Pressure on a nerve will prevent the passage of the current, while

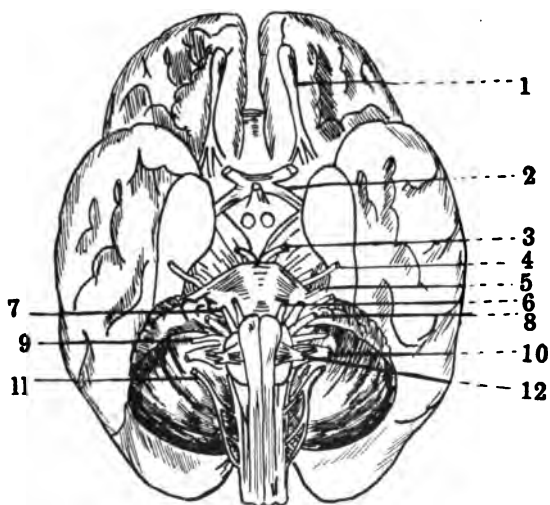FIG. 18. Brain from below, showing the nerves numbered. 1—smell, 2—sight, 8—hearing, 9—taste. The others supply muscles, skin, teeth, etc.

the axis of the nerve fiber, unlike the electric wire, is presumably worn by its activity. The cells which surround it are thought to supply it with food and oxygen and perhaps to assist it in carrying the nerve current, but their function is not well understood.

The brain. For the study of the brain, cut a calf's head into right and left halves. This can easily be done by splitting the nasal cartilage with a knife and by sawing carefully through the bones. Then the hemispheres of the brain should be carefully separated and the cerebellum, medulla, etc., cut exactly through the middle with a sharp knife.
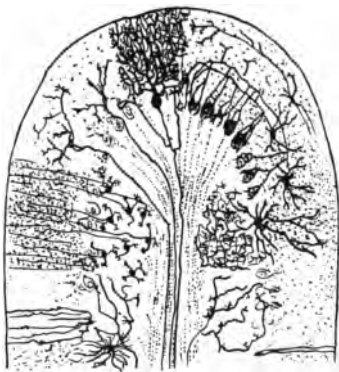
FIG. 19. Cross section of a small lobe of the cerebellum, highly magnified, showing the arrangement of the nerve cells, their dendrites and axons.

1. Notice the medulla oblongata at the large opening in the base of the skull. Its downward continuation is the spinal cord. What color is it? How does it feel?

2. Trace the medulla forward. Does it lie along the floor, or in the upper part of the cranial cavity?

3. The cerebellum lies just above the medulla. What color and how thick is the pillar or stem that fastens it to the base of the brain?

4. What two colors appear in the cut surface of the cerebellum? Which color is in the middle of each lobe? Which at the margin?

5. The large portion of the brain remaining is the cerebrum. What part of the cranial cavity does it occupy?

6. The band of fibers, corpus callosum, connecting the right with the left hemisphere was cut in dividing the brain. What color is it?

7. Make a cut in the cerebrum. Tissues of what two colors do you see? Which is in the middle of the lobe? Which is at the surface?

8. The folds in the cerebrum and cerebellum increase the amount of which tissue—the white or gray? The gray contains the cells, the white the connecting fibers.

9. Lift the brain *partly* out of its setting, but do not break any threads; the white strings extending from it are nerves. To what part of the brain are they attached?

10. Is the part of the membranous covering of the brain which adheres to the skull tough or tender? Is it smooth or rough inside? Does this part dip into the furrows of the cerebrum? into the deep notch between cerebrum and cerebellum?

11. Does the delicate membrane which adheres to the brain dip into the convolutions?

12. Make a general sketch showing the parts of the brain and the nerve attachments. Make a sketch of a section through the cerebrum, and another through the cerebellum, showing the arrangement of the white and gray matter in the lobes.

Localization of function. The nerve tissue in the large lobes of the brain is composed of central neurons and fibers communicating with them. The cells of the peripheral neurons, those which bring in the currents and carry them to muscles, to glands, or to outlying ganglia, are located along the spine or in small ganglia in the head. The brain receives currents from all the sense organs of the body, and sends out currents to all the voluntary muscles. One special part of the brain is the sight center,

another part the hearing center, another the taste center, and so on. See Figure 20. Nerves of touch from the hand come to one part of the brain, from the foot to another part, from the chest and the back to still other parts. In like manner the motor centers are localized, cells of one definite area sending currents to one muscle or set of muscles, and those of another area to other muscles. The areas of both sensory centers and motor centers are not
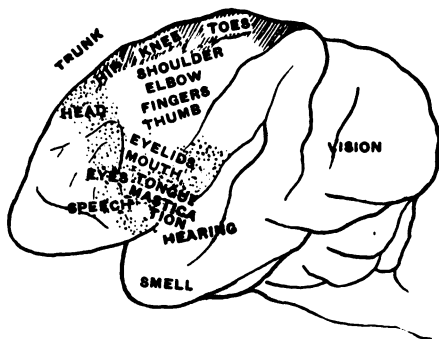
FIG. 20. Diagram of sensory and motor areas in the brain of a monkey.

altogether distinct from one another, but overlap at the margins and sometimes one area largely covers another. The frontal portion of the cerebrum, which is not a motor or a sensory center, is thought to be the region especially involved in thinking, though other centers also take part in this activity. It receives currents from other centers and through a complicated network of cells

and connecting fibers, in a way that has not been thoroughly worked out, it establishes relationships —and we have ideas, thoughts, and emotions.

Spinal cord anatomy. For the study of the spinal cord, get about four inches of sheep neck. Roughly trim off the muscles and cut out the dorsal arches of the vertebrae by sawing along each side. If the material is not fresh, the cord may have shrunk;
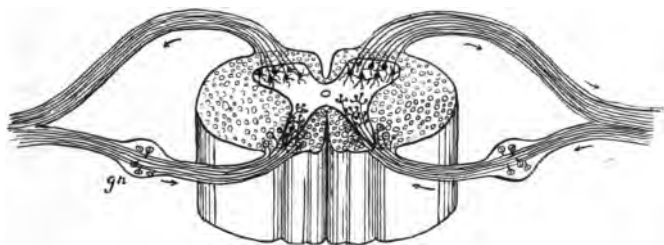
FIG. 21. Diagram of a portion of the spinal cord, from behind. gn—spinal ganglion. The cells, in the gray matter, and the fibers, in the surrounding white matter, are disproportionately magnified. Note that some incoming fibers run to the gray matter and some send branches which run in the white matter lengthwise of the cord.

it should fill the canal snugly. Observe whether each spinal nerve joins the cord by a single strand or by several strands. Each nerve has two roots, not easily seen without a more careful dissection than you have been asked to make. The ventral root is composed chiefly of fibers which carry currents out to muscles, and is therefore called the efferent or motor root. The dorsal root carries currents from the touch organs to the cord and is hence called the afferent or sensory root. The

cells, to and from which the fibers of the dorsal root run, are located in the spinal or dorsal ganglion.

The gray matter of the cord contains the ganglion cells; some, along the dorsal side, for receiving currents from the spinal (dorsal) ganglia and for communicating with other cells of the cord or of the brain; and some, along the ventral side, for sending out currents to the muscles, glands, and small ganglia. The nerve fibers compose the white matter of the cord. They carry currents from one spinal cell to another and connect the cells in the brain with those in the spinal cord.

1. Where is the spinal ganglion? See Fig. 21.

2. Is the outer membrane covering the cord tough or tender?

3. Describe the inner membrane.

4. The membranes covering the cord are continuous with the corresponding membranes of the brain. Does the cord itself feel soft or firm?

5. Tissues of what two colors appear in the cut end of the cord?

6. Sketch to show the relative positions of these tissues. A hardened and stained specimen will show them better than the fresh material, and should be used if accessible.

Function of the cord. The spinal cord acts as a local center, thus relieving the brain of a great deal of work. It controls, largely, the digestive organs and the blood system. It receives the incoming nerve currents from the skin, joints, and muscles

below the head, sends on to the brain the messages which need the attention of that center, and attends to the minor matters it-self, sending stimuli to the muscles for the necessary activities. Reflex actions in the body below the head are produced through the spinal cord and medulla. They do not involve the brain proper.

Sympathetic system. The plan of controlling involuntary activities by local ganglia is further carried out through what is sometimes called the sympathetic system. Fig-ure 22 is a diagram repre-senting one of the two
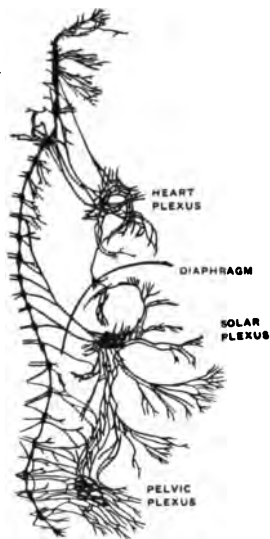
FIG. 22. One of the two sympathetic nerve chains, and the median ganglia, seen from the side.

chains of ganglia situated one on each side of the spinal column. It includes also three groups of ganglia and a network of nerves situated in about the middle line of the body, and connected with the two chains and with the spinal cord and brain.

Nerves run from the sympathetic centers to the organs of the chest and the abdomen, and to many of the arteries in the skin, the glands, and the muscular parts of the body.

1. Name the organs which the diagram shows are in part supplied with nerves from the sympathetic center.

2. With how many ganglia is the heart plexus connected?

3. Where is the solar plexus in relation to the diaphragm?

4. With how many ganglia in the main chain does the solar plexus seem to be connected?

5. With what besides the ganglia of the main chain is the plexus in the pelvis connected?

6. Does every ganglion send off nerves (at the left Fig. 22) to join the spinal nerves?

Habit. The first time we try to do a thing the movements are slow and awkward. It is with difficulty that the nerve currents are directed along the desired channels. With each repetition of the motion the nerve currents move more easily, till they come to flow with the utmost ease and swiftness along the well established channels. It is so not only with muscular movements but also with thoughts and feelings. When you attack a new kind of problem in algebra the nerve currents do not move smoothly along the new road, but when you have solved a few problems of this kind, the nerve currents have established their course and the work is less difficult. Nerve currents always prefer the established routes. The actions, thoughts, and feelings to which we have become accustomed are our habits. They require little effort or attention. Habit is deep-seated in the

nerve system, and is not easily altered. How important it is, then, to establish good habits instead of bad! During conscious life we must continually think and act in some sort of way. If we are not forming habits of right thinking and right acting, we must be forming wrong habits. The formation of good habits prevents the formation of bad ones, and the only sure way to correct a bad habit is to form a good one to take its place.

Education. Education consists in establishing desirable nerve routes so that the mind and muscles act quickly and easily to accomplish the things we desire. No one can educate you. Filling your mind with facts is not education. The facts are things to be used. Schools, teachers, and books are helps, but you must develop your own powers, acquire habits of accurate thought and desirable conduct by your own persistent, careful practice. The greater your activity and the wider its range, the broader and more thorough will be your education.

Stimulants and narcotics. The effect of stimulants and narcotics upon the nerve system is greater than upon other tissues. Since this system controls the muscular, and, at least to some extent, the secretive and assimilative activities, these drugs exert an influence over the whole body. Alcohol affects the various nerve centers in different ways. The centers that control the blood circulation re-

spond quickly to small quantities of alcohol. The heart beats more rapidly and there is an increase in the blood supply, especially to the brain, skin, and mucous membrane. This makes the thoughts more lively for a time. The skin becomes red and the mucous membrane more active. A larger quantity of alcohol depresses the higher nerve centers. The judgment, which sits in control over all our voluntary activities, is impaired, the reins of control are loosened, the tongue runs riot, the actions are ludicrous or vicious, as the ungoverned imagination suggests. A still larger quantity of alcohol deadens both motor and sensory centers. The body has little feeling and moves sluggishly and uncertainly.

The occasional use of small quantities of alcoholic liquors sometimes produces no noticeable permanent effect on the nerve system. But to the careful experimenter, it has a very noticeable temporary effect. It decreases markedly the quickness and the power of both mental and muscular actions. And in the ordinary temperate drinker the nerve centers are permanently dulled; they respond less promptly and less vigorously to the calls made on them. The habitual excessive use of liquor produces the chronic condition of exhausted and inefficient nerves, manifested in the shambling gait, thick speech, and bleary look of the old toper. The nerve trunks in hard drinkers are sometimes so diseased (neuritis) that they not only fail in their function but cause great pain.

Saint Vitus Dance. Children sometimes suffer from St. Vitus dance, a twitching of the muscles due to perverted nerve impulses. Fatigue, lack of exercise, and germ-infected air are among its causes. A physician should be consulted when the symptoms first appear. With more hygienic living, the nerves usually regain their normal control of the muscles.

Sleep. Plenty of sleep is necessary to a sound nervous system. During sleep the protoplasm of the nerve cells, which has become perceptibly shrunken and exhausted by the activities of the day, is restored to its fullness and strength. In the quiet of the country, a tired body drops into sound sleep early, and awakes in the morning with a fresh, vigorous nerve system. Dwellers in the bustling city, living under a higher nervous pressure, are in greater need of sleep, but are more tempted by the excitement and press of multitudinous duties to deny themselves the indispensable rest. Though people differ considerably in the amount of sleep they require, adults should have seven or eight hours a day, and children nine or ten hours. The sleep should be quiet, not troubled by distressing dreams or broken by the mind's dwelling on the perplexing problems of the day. To this end the last half hour or so before retiring should be given to relaxation. Students should do their hard work in the morning, and reserve the lighter work for

evening. No study after nine o'clock, is a good rule. The boy or girl who digs at his lesson until eleven or twelve o'clock at night is pretty sure to be dull, irritable, and inefficient the next day. His nerve cells are not at their best. The best preparation for mental or physical strain is a good sleep.

Hygiene. The superiority of man to the lower animals is most conspicuous in his nerve system. It is precisely where civilized man is most developed that he breaks down most easily. We live in what has been called an age of nervous prostration. The speculator watching the market, the society woman madly pursuing a program, and the scholar striving for honors or promotion, all are the frequent victims to the disease of the age. We should learn to relax, to rest. Some time each day should be given to quiet and meditation. The various sorts of mental healing often produce good only because they establish nerve quiet, and direct the thoughts away from self. One can live under good conditions of physical hygiene, and yet become a nervous wreck, if he is the subject of constant nervous irritation. Great minds cultivate poise and equanimity. We are wont to magnify the small ills of life, if there are no large objects to occupy us. One engaged in thoughts of science, government, or philosophy is not worried over his own petty affairs of life. The dignified pursuit of a worthy object in life gives tone and poise to the nerve system.

CIRCULATION

You already understand that the food prepared by the digestive organs, and the oxygen taken in through the lungs, must be distributed throughout the body, so that each cell shall receive its share; and that the carbon dioxide and other products of oxidation must be removed from the cells. This work is done by the circulatory system. The essential parts of this system are, first, a circulating fluid; second, an engine to make it move; and third, a system of tubes to convey it. This gives a three-fold division of the chapter.

BLOOD AND LYMPH

The blood consists of cells called corpuscles, and the fluid in which they float. The corpuscles are of three kinds: the red corpuscles, the white corpuscles, and the blood plates. The last named are so small and disappear so quickly in dead blood that little has been learned about them; they may be fragments of white corpuscles.

Red corpuscles. The red corpuscles are shaped like coins, thinner in the middle than around the rim, and are about $1/3500$ of an inch in diameter.

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They are composed of protoplasm rather stiffer than that in most cells, and although they can be bent they spring back to their disc-like shape. Since the corpuscles are alive, that is, composed of protoplasm, they die of injuries, wear out, and must be replaced. They are not known to multiply by dividing, as most cells do, but are produced in certain cells of the red bone marrow and in other places. The red color of the corpuscle is due to a substance, called hemoglobin, contained within the protoplasm.

The hemoglobin performs the most important function of the red corpuscle, that is, to carry oxygen. When the blood passes through the lungs, all parts of it absorb some oxygen from the air in the lungs, but the hemoglobin makes a chemical combination with the oxygen and so is able to absorb many times as much as it could hold in simple solution. As the blood circulates through the body distributing the oxygen everywhere, the hemoglobin goes through a reverse chemical change, giving up its oxygen to the surrounding fluids, which pass it on to the protoplasm in the cell.

White corpuscles. There are several varieties of white corpuscles. They are fewer in number than the red, about one white to every six hundred red. They are colorless, larger in size than the red, and composed of more watery protoplasm. When they

die they draw together into spheres and are usually so seen under the microscope. In life they get about by a flowing motion, changing their shape in such a way that one corpuscle may take, in a few minutes, all the forms shown in Figure 23. Of course the white corpuscles float along in the blood to all parts of the body, but they are not restrained as the red are within the blood tubes. They are able by their flowing movements to get through the walls of the capillaries and move about almost everywhere in the body. They congregate in large numbers wher-

FIG. 23. Red blood corpuscles. a—surface of the disc; b—edge; c—in rouleau; d—a colorless corpuscle, showing the four forms it took within a few minutes, and the spherical form, magnified less than the red.

ever the tissue is injured, at wounds or sores, and may do some work in repairing the injury. Their most important evident function, however, is in destroying bacteria. (See page 225.) This they do by flowing around the germs and by digesting and assimilating them.

The plasma. Though not protoplasm, the plasma contains all the elements that go to make up that fluid. It holds in solution almost every substance of the body that is soluble; it serves as a fluid to float along the corpuscles, and is the food of the protoplasm. The plasma readily oozes through the walls of the capillaries and gets into

the minute spaces in the tissues. There we must change its name and call it lymph.

The lymph. The white corpuscles and plasma form the lymph, which constantly bathes the cells, circulating slowly, bringing food and oxygen to the protoplasm and carrying away the products of oxidation. It is thus an intermediary between the cells and the blood vessels. Some of the lymph gets back into the blood through the walls of the capillaries and becomes a part of the plasma. The remainder is collected by a set of tubes called the lymphatics and carried back into the blood system.

Coagulation. When blood vessels are broken and the blood runs out into the spaces among the cells or escapes from the body, it soon coagulates or clots. It sometimes clots also within the vessels when they are injured. A ferment forms in the injured cells or in the dying corpuscles. It acts on the plasma, changing part of it into minute threads called fibrin. The fibrin threads extend through the mass of blood causing it to have the appearance of red jelly. The process is similar to that which occurs when sour milk gets thick. If the blood contains considerable lime salts it clots more readily. The fibrin threads soon contract, drawing with them the entangled corpuscles and forming a compact clot. The part of the plasma that has not changed into fibrin is squeezed out of the

contracting clot as a straw colored liquid called
serum. The serum usually drains off or evaporates,
leaving the stiff clot behind. The lymph clots in
the same way as the blood, but since it has no red
corpuscles, its clot is colorless. Sometimes the skin
is scraped, not deep enough to cause bleeding, but
so that the lymph oozes out and forms a clot, which
dries to a colorless scab. The function of the clot is
to plug up the wound and so prevent further bleed-
ing. If the blood did not clot, a cut in even a small
vein might drain away much of the blood and so
be fatal.

Blood Tubes and Lymphatics

The arteries. The blood is carried from the
heart by arteries. They are stiff, strong-walled
tubes, the largest about the diameter of the thumb.
From the larger tubes smaller ones branch off and
subdivide, distributing the blood everywhere
throughout the body. The blood is forced through
the arteries by the contraction of the heart. We
do not always appreciate the strength of the heart's
contraction and the force with which the blood is
pressed into the arteries. If a large artery were
an inch in diameter, the blood in it would press
against an imaginary partition across it with a
force of four pounds. To withstand this great
pressure of blood, the arteries must have strong
walls; the walls must be elastic, to yield a little
when the heart contracts and the blood comes with

most force, and to spring back when the pressure is less between heart beats. This strength and elasticity is obtained by a network of yellow elastic fibers which compose most of the wall of the large arteries. Beside the elastic fibers there are small non-striated muscles, and at the outside a web of inelastic fibers. The arteries are lined with a smooth membrane composed of a single layer of

VEIN

CONNECTIVE TISSUE
MUSCULAR COAT
ELASTIC COAT
ENDOTHELIAL COAT
ARTERY
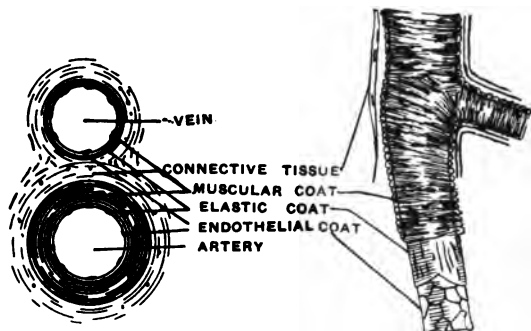
FIG. 24. Diagrammatic representation of the walls of blood vessels. In the side view the outer layers are cut away to expose the inner.

flat cells edge to edge. The blood pressure in the large arteries is much greater than in the small, and so their walls are thicker. As the arteries get smaller there is a steady dimunition in the quantity of the strong fibers and muscles, until there are left around the lining membrane only a few muscle cells. When the tubes get still smaller, and there is no covering over the lining membrane, they are capillaries.

The capillaries. Almost everywhere in the body, making a network connecting the arteries with the veins, are the capillaries. Their diameter is about 1/3000 of an inch; their length averages about 1/25 of an inch, but they vary a great deal, some being several times as long as others. They are so close together that a fine needle could not be thrust into a tissue without destroying a number of them. Their walls are too thin to be measured. Describe the shape of the cells which make up the wall of a capillary. (See Figure 25.) The blood goes through the network of capillaries in an irregular course, at times reversing its direction in some tubes, going now faster, now slower, but always from the greater pressure of the arteries to the lesser pressure of the veins. As the blood flows
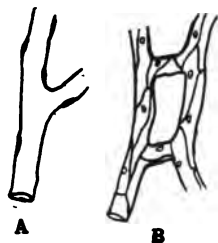
FIG. 25. Capillaries, much magnified. A— section; B — surface showing cells.

through the capillaries some of its plasma passes through the thin cells and becomes lymph. Some of the white corpuscles get through the cement between the cells and wander off in the lymph spaces, while the oxygen passes out to the protoplasm that needs it. Moving in an opposite direction, carbon dioxide goes from the tissue into the blood, and some lymph and white corpuscles return.

Veins. The function of the veins is to gather the blood from the capillaries and return it to the heart. The smallest veins are but little larger and stronger than the capillaries. From these the blood flows into successively larger tubes until all that in the lower part of the body is collected into the large trunk called the ascending vena cava, whence it flows to the heart. The walls of the veins are composed of the same tissue as the walls of the arteries, but since there is less blood pressure in the veins, the walls do not need to be so strong. The arteries are stiff like hose pipe, because of the large number of elastic fibers in their walls; the veins are soft and collapse when empty, because their walls contain only a small quantity of soft fiber.

Valves. It would be easy to press the blood in the flabby veins back toward the capillaries, if it were not for the valves, little pocket-like folds of membrane in the lining of the veins. These valves have no power of motion in themselves. They lie passive in the blood current, and while the stream is moving toward the heart they are pressed against the sides of the tube, but when the stream starts to back up their free edges are caught and thrown out, opening the pocket and closing the vein. The venae cavae and veins surrounded by soft organs, as in the brain and the abdomen, have no valves.

The arteries are without valves except at the

heart. The blood pressure in the arteries is strong
enough to keep the blood always moving forward,
and the walls are so stiff that they are not easily
compressed and the blood driven back.

The lymphatics. The work of the veins in
returning to the heart the circulating fluid is sup-
plemented by the lymphatics. A
large part of the plasma and of
white corpuscles that passes out
of the walls of the capillaries
does not return into the capil-

FIG. 26. A longi-
tudinal section of
a vein with valves
closed.

laries. It is collected from the intercellular spaces
by the lymph tubes, brought into the lymph trunks,
and finally back to the general blood circulation.
The small lymph tubes were thought to be open
at the end to the various cavities of the body and
to the intercellular spaces, but recent studies seem
to show that they are closed. Yet the contents of
the intercellular spaces is readily taken up and car-
ried off by the lymphatics,—bacteria and other
minute particles as well as fluids. The lymphatics
then perform a sort of scavenger function, picking
up and removing whatever lies among the tissues.
Here and there through the body lymph tubes con-
verge into small centers called glands or nodes,
from which other lymph tubes lead on toward the
lymph trunks. The function of the glands seems
not fully known. Some varieties of white corpuscles
are produced in them, and the lymph is to some

extent filtered in passing through them. Most of
the bacteria are caught, delayed, or destroyed, but
some get through. Along the stomach and intes-
tines the lymphatics pick up a portion of the ab-
sorbed food. They are here called lacteals, because
of the milky appearance of their contents while
digestion is going on.
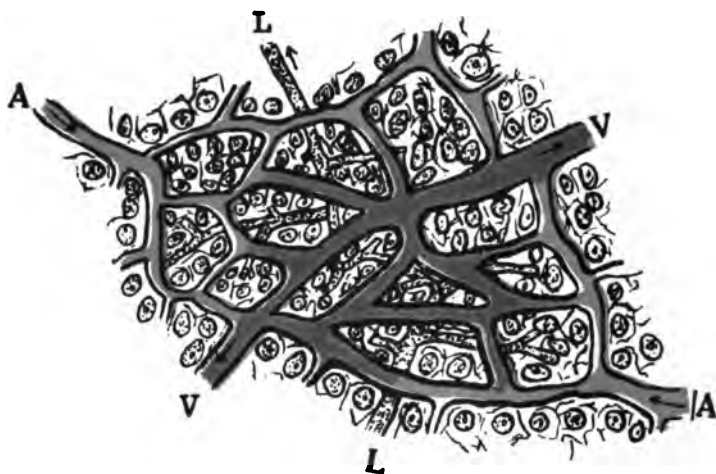
FIG. 27. Diagram of capillaries and the beginnings of the
lymphatics. A—arteries; V—veins; L—lymphatics.

1. The main receiving center of the lymph system lies
on which side of the diaphragm? See Fig. 28. It re-
ceives the lymph from the lower part of the body.

2. Describe the location of the trunk (thoracic duct
or cysterna chyli) that carries the lymph from this recep-
tacle to the vein.

3. What vein does it join?

4. At what place?

RIGHT
LYMPHATIC
DUCT

SUBCLAVIAN
VEIN

INTERNAL
JUGULAR

FROM
HEAD

FROM
ARM

SUBCLAVIAN
VEIN

THORACIC
DUCT

THORACIC
DUCT

DIAPHRAGM
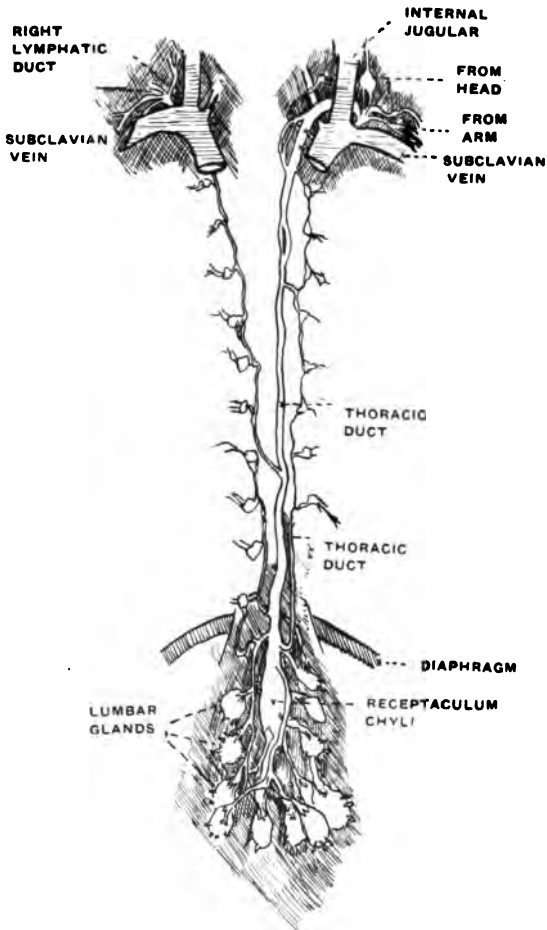
LUMBAR
GLANDS

RECEPTACULUM
CHYLI

FIG. 28. Central lymph trunk (Thoracic duct), the nodes or glands and the tubes. For the positions of the veins, see Fig. 34; jugular vein from the head, subclavian from the arm.

5. Just before the duct joins the vein it receives branches from what places?

6. How is the lymph from the right side of the head and chest and from the right arm disposed of?

7. Lymph tubes and nodes are scattered all through the body, but are especially numerous in certain places.

8. Where are nodes shown in Fig. 29?

FIG. 29. Some lymphatics of the head, neck and axilla (arm pit), lying just beneath the skin. Note the point to which all the lymph tubes converge, where the lymph is poured into the vein.

Veins. Place your left hand on a piece of paper and trace its outline with a pencil. Sketch in this outline the veins you can see in the back of the wrist, hand and fingers. If you tie a bandage around your arm the veins will stand out more clearly. If your own hand is so plump that you can-

not see the veins clearly, sketch from the wrinkled
hand of an elderly person. With a bandage or with
your right hand, compress the left wrist; slowly and
carefully slip the compression down toward the
hand. The veins seem unusually swollen on the
proximal (near) side of a valve. Note their ap-
pearance on the distal (far) side. In your sketch
mark the locations of all the valves you can find.

1. Are the veins in the back of your hand arranged
like the tributaries of a river, the smaller separate from
each other and flowing into the larger, or are they con-
nected by frequent cross veins?

2. What advantage is there in their arrangement?
They are said to anastomose.

3. All the blood vessels which you see through the
skin are veins. There is also a set of veins lying deep
in the arm. What is the advantage of two sets?

4. Why have the arteries the deep position only?

Figure 30 shows diagrammatically the principal ar-
teries of the arm and hand.

1. If the circulation through the radial artery were
stopped, how would the hand receive the blood supply?

2. Trace the course by which the blood would get to
a branch about the middle of the ulnar artery, if the
ulnar were closed near its proximal end?

3. Is each finger supplied by one or by two branches
from the palmar arch?

4. Do the veins [Fig. 31] of the arm have more or
fewer anastomosing branches than the arteries?

5. Why is this desirable?

6. Why are there more large veins than arteries in the
arm?
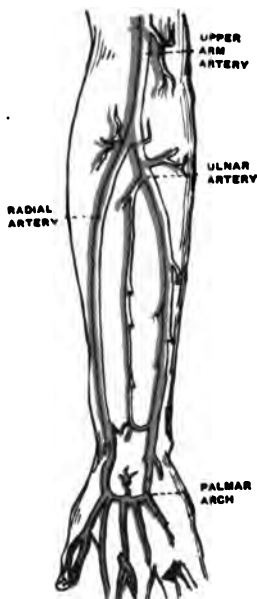
FIG. 30. The chief arteries of the arm and hand. Each finger is supplied by two branches, as is represented in the first finger.

FIG. 31. The principal superficial veins of the arm. The hand and three fingers are left blank.

FIG. 32. Arteries just under the skin of the head.

UPPER ARM ARTERY

ULNAR ARTERY

RADIAL ARTERY

PALMAR ARCH

FIG. 30.

CAROTID ARTERY

FIG. 32.

FIG. 31.

7. Figure 32 shows the superficial arteries of the head. Where does the main trunk lie? Put your finger over it in your head and neck and feel the pulse as many places as you can.

8. Do the smaller arteries take a crooked or a straight course?

9. Describe the location of the veins of the head and neck shown in Fig. 33.

EXTERNAL
JUGULAR

INTERNAL
JUGULAR
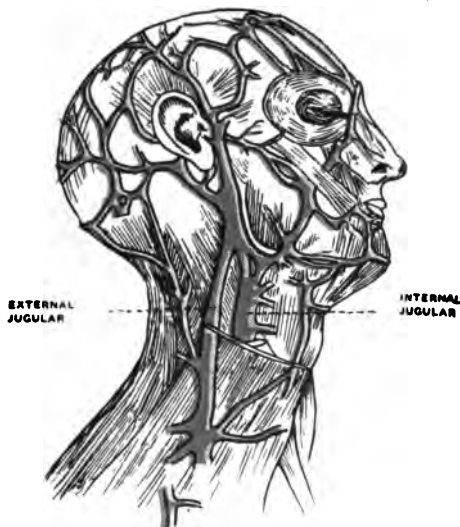
FIG. 33. Some veins of the head and neck.

10. Why should the large veins be located near large arteries?

11. Are anastomoses in the veins frequent or not?

12. The general plan of the blood circulation is shown in the diagram, Fig. 34. Compare this with the less diagrammatic representation in Fig. 35.

13. What vessel receives the blood from the left ventricle and distributes it to the body?

14. The first large branches to leave the aorta carry blood to what parts of the body?

15. What is the name of the main artery continuing from the arch of the aorta and running downward, lying
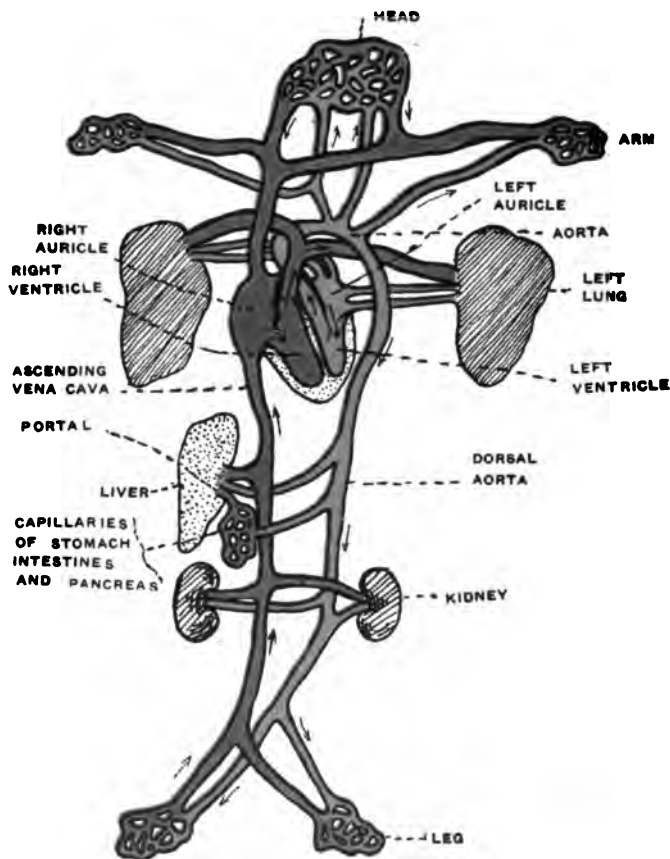
FIG. 34. Diagram of the blood circulation. Blood containing much oxygen is scarlet, blood containing much carbon dioxide and little oxygen is dark red. In the lungs, liver, and kidneys the blood goes through sets of capillaries.

anterior to the vertebral column? Its very small branches, to the chest and elsewhere, are not indicated.

16. Trace, by naming in order the vessels through which it goes, the course of the blood from the heart to the kidneys and back to the heart.
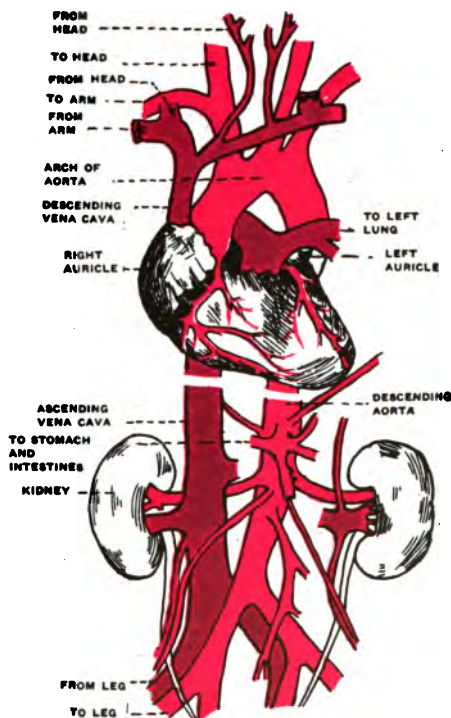
FIG. 35. The heart and chief blood vessels in the chest and abdomen.

17. To what chamber of the heart is the blood returned?

18. From which chamber does the blood go through the pulmonary artery to the lungs?

19. To which chamber does it return from the lungs?

20. How many pulmonary veins enter the heart?

21. What organ receives blood from a vein as well as from an artery? The portal system is better shown in Fig. 36.

22. From what organs do the branches of the portal vein collect blood?
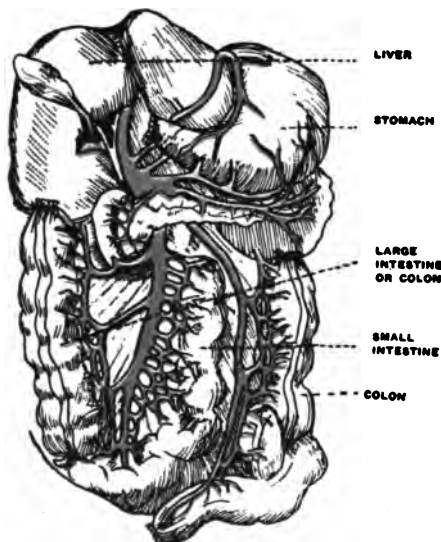
FIG. 36. The portal vein and its tributaries. The transverse colon, part of the duodenum, etc., are cut out.

23. Trace from the heart and back to the heart the course of the blood that supplies the pancreas.

24. Trace the course of the blood that supplies the left side of the head.

25. Trace the course of the blood to the right arm and back.

26. Starting from the left ventricle, trace the course of the blood to the leg and back again.

Why the blood circulates. Each contraction of
the heart sends blood spurting through the arteries.
This impulse of the blood causes the walls of the
arteries to give or distend. When the heart mus-
cles relax, the elastic artery walls spring back to
their former diameter, pressing on the blood and
sending it forward in a continuous stream. The
blood is forced into the capillaries, crowding that
which is already there into the small veins. The
blood in the small veins is pushed into the larger,
ever crowding forward that which is ahead of it.
Thus the chief power that makes the blood move
from the heart through all the tubes and back to
the heart is the heart muscles.

There are, however, two accessory forces that
we should notice. Every time a vein in any part
of the body is compressed, either by the bending
of a joint or by the contraction of a muscle, the
blood is squeezed out of it and must move toward
the heart, since the valves prevent a backward
motion. When the compression is relaxed, blood
flows into the vein again. Thus exercise quickens
the circulation. Determine why the arteries are
less affected by these compressions than are the
veins.

When we expand the chest in breathing, the
pressure inside the chest is lowered, and blood from
veins in the abdomen, and especially in the neck,
is forced into the chest through the large veins

leading to the heart. In exhalation the contraction of the chest cannot force the blood back through the veins, since the valves prevent. Thus respiration is a process of pumping the blood in the large veins into the chest.

The lymph is forced through the lymph tubes in almost the same way that the blood is driven through the veins. In the tissue, the lymph is under slightly greater pressure than in the large tubes, hence is flows slowly toward the lower pressure. Every compressing movement squeezes the lymph tubes, and the valves direct the flow toward the heart. The main lymph trunk runs through the chest, and the lymph, as well as the blood, is pumped with every respiration.

Rate of blood flow. The blood moves quickly in the large arteries and more slowly in the small, averaging about twelve inches per second. In the veins the blood moves more slowly, about eight inches per second on the average. In the capillaries the blood moves most slowly. It is there most spread out, that is, the aggregate capacity of the capillaries is greater than that of the arteries that supply them, or the veins into which they discharge. Of course the short circuits, for example to the head, are made in less time than the long circuits, such as to the hands and feet.

The lymph flows more slowly and more irregularly than does the blood. A substance injected

into a lymph space has been found in the blood, having passed through the small lymph tubes, the nodes, and trunks and nearly a complete blood circuit, in a few minutes.

1. If the blood weighs one-twelfth as much as the whole body, and if a ventricle holds about three ounces, and the heart makes eighty beats a minute, how long would it take to pump a quantity of blood equal to all of yours through your aorta?

Regulation of the amount of blood. It is very important that the amount of blood going to each part of the body be carefully regulated. Just after dinner a large quantity of blood is needed in the stomach, and when the food has passed on to the intestine less blood is required in the stomach. When we are studying diligently, much blood is needed in the brain, and when we are sleeping less blood is needed there. How the supply of blood is controlled is the question before us now.

If the heart beats more rapidly, more blood is sent through the arteries to all parts of the body. If the heart beat becomes slower less blood goes everywhere. The regulation of the supply to any organ must depend not upon changes in the heart beat, for that affects the whole body, but rather upon directing to the particular organ a larger or smaller portion of the current going through the general arteries. This regulation is accomplished by changes in the diameters of the arteries or the

veins, or of both arteries and veins of the particular organ. When the circular muscles in the walls of an artery relax, the blood pressure distends the tubes. Since the enlarged tubes offer less resistance to the blood, a larger and more rapid stream flows through them. This larger stream presses more vigorously into the capillaries, distending them slightly and flowing more rapidly through them, and through the veins beyond. When the circular muscles in the walls of an artery contract, the diameter of the tube becomes less, the blood meets more resistance and flows through in diminished quantity.

The muscles in the walls of the veins and arteries are under the control of nerves (called vaso-motor nerves) which cause them to contract or to relax just as the quantity of blood required is less or greater. The changes in the diameter of arteries, you observe, is not in the large trunk vessels, but in the smaller tubes which supply organs or parts of organs.

The muscles of the walls of some small blood vessels lose their "tone," their power to contract and bring the tube to its normal size, so the tubes are distended with a slowly moving dark-colored blood and they become noticeable in the skin. Repeated exposure to the weather, habitual excessive use of stimulants, or simply old age may produce such results.

1. When you blush are the arteries which supply the skin of the face enlarged or constricted? Are the muscles relaxed or contracted?

2. When your throat is inflamed what change has occurred in the blood vessels of the mucous membrane?

C. The Heart

General plan. The function of the heart is to make the blood move in a continuous stream through the blood tubes. Its essential structure is a cavity or chamber, called a ventricle, surrounded by muscle. Blood is received into the open ventricle, then the muscle contracts and squeezes it out into the artery. Just above the ventricle is a small chamber called the auricle, through which the blood from the veins passes on its way to the ventricle. While the ventricle is contracting and cannot receive blood, the auricle expands and holds for half a second the blood coming from the veins, then passes it on into the opening ventricle. The heart is a double pump with two auricles and two ventricles. All the blood goes through a double circulation—to the lungs to get oxygen and to give off carbon dioxide and to the remainder of the body to distribute the oxygen and nutritive materials, and to collect the waste.

The human heart is so nearly like that of the sheep and the pig that we may well study the organ from one of these animals. If you get from the butcher the whole pluck (heart, liver and lungs)

you will have the entire heart together with the
largest arteries and veins adjacent. If you buy the
heart only, the auricles and the tubes are usually
trimmed away. Make a cut through the muscular
wall of each chamber large enough to allow you to
explore the interior thoroughly.

STUDY OF A SHEEP'S HEART

1. Find the four chambers of the heart. Which have
thick walls? Which have thin walls? Why are they so?

2. How many veins enter the right auricle? · Pass a
seeker (a small, smooth, blunt-pointed rod) through each.

3. With a seeker or with your finger explore the veins
entering the left auricle. Where do they come from?

4. Explore the artery leading out of the right ventricle.
Where does it go? Describe the semi-lunar valve in it.

5. Explore the artery leading from the left ventricle.
Describe its position and its valve.

6. How do the walls of the arteries differ from those
of the veins?

7. About how large is the opening between the right
auricle and the right ventricle? Describe the tricuspid
valve guarding it. To what are the lower ends of the
valve threads (chordae tendinae) attached? What is
the function of these cords?

8. Point out the difference between the mitral valve
(left side) and the tricuspid.

9. Describe the inner surface of a ventricle; of an
auricle.

10. The pericardium, or sack enclosing the heart, is a
serous membrane. [See Fig. 43.] If it is not altogether
cut away, describe its surface.

11. Make a diagram showing the chambers, valves,

veins and arteries of the heart, and by arrows indicate the course of the blood through them.

Rate of heart beat. Whenever the heart contracts the blood is forced into the arteries with such pressure as to distend these tubes perceptibly. They become harder and tend to straighten out. These changes can easily be felt by pressing the fingers gently over an artery that lies near the skin. This is feeling the pulse.

1. Get the pulse in your wrist between the radius and the tendons. Count it for one minute. What is the rate of the heart beat?

2. Exercise briskly for two or three minutes; count the pulse again. What is the rate? Why need it be different.

3. Let each pupil of the class report the rate of his heart beat while sitting still, and also after exercise; get the averages. They are probably somewhat higher than adult averages. A baby's heart beats 120 to 130 times a minute.

Character of heart beats. The character as well as the rate of the pulse is important. Most hearts do not beat with perfect regularity, even in health; and disease produces a variety of changes in both the rate and the character of the pulse.

1. Get the pulse of your body in as many different places as you can. Is it usually in an exposed or in a protected situation?

2. Are your pulse beats steady like the tick of a clock, or do the intervals between beats differ?

3. Is there any difference in the strength of the beats?

Innervation. The beating of the heart, like all
other activities of the body, is under the control of
the nerve system. It seems probable that the heart
muscle can contract without nerve stimulus, yet the
rate and the strength of the heart beats are con-
trolled by the nerve centers. Within the heart are
a number of small ganglia from which nerves go to
the muscles of the organ. (See Figure 22.) These
local centers are controlled by nerves from the
spinal cord, medulla and sympathetic ganglia. The
nerve fibers from these various centers are rather
complex. Some fibers of a strand carry currents
which make the heart beat more rapidly, and other
fibers carry currents which make it beat more
slowly. A blow in the "pit of the stomach" may
retard or even stop the heart beat. What large
sympathetic center does it affect? (Page 75.)

Nourishment of heart muscle. The heart muscle
is nourished, not by the blood that it pumps, but
by a small amount supplied by a special artery.
The blood passes through the large chambers of
the heart and in so doing does not get into the
tissues of that organ. A small artery (coronary)
branches from the aorta just behind the semi-lunar
valve and sends distributaries throughout the heart
muscle. The blood can flow into the muscle only
when the muscle is relaxed, and every contraction
squeezes the blood out of the capillaries and small
veins and into the larger veins. Why does the

coronary artery branch from the aorta *behind* the valve; that is, on the side away from the ventricle?

Hygiene. A good circulation means a strong heart, elastic vessels, and the ability to change readily the quantity of blood circulating to any part of the body. Exercise is a prime necessity in maintaining a good circulation. It should usually be moderate, but occasionally extremely vigorous, that the heart and arteries may be trained for any requirement of the body. If one has a serious defect in the heart, violent exercise should be avoided, and the moderate exercise should be carefully supervised by a competent physician.

There is a progressive hardening of the vessels of old people. This accounts for their sudden fits of dizziness on rising or on unusual mental exertion. The arteries, having lost much of their elasticity, do not dilate promptly to meet the call for increased blood supply. The foremost cause of early arterial degeneration is alcohol. "A man is as old as his arteries," and a drinker of alcohol is old before his time. The heart also suffers from alcoholism. Its muscles waste away and some fibers partly turn to fat. The organ, which is normally firm, may become so flabby through alcoholic degeneration that, if held by its tip, it falls over like a rag.

RESPIRATION

We shall study in this chapter how the cell gets oxygen from the atmosphere and how the carbon dioxide produced in the body is carried away. The protoplasm of each cell performs an act of respiration in taking from the surrounding lymph the oxygen it needs and in transmitting to the lymph the carbon dioxide it produces. This is called internal respiration. The lymph gets oxygen from the blood and brings carbon dioxide back into the blood.

Why the gases move, the oxygen from the blood to the cell and the carbon dioxide from the cell to the blood and lymph, may be briefly explained as follows: A gas always tends to distribute itself evenly through space. If there is more of it in one place than in another, some moves from the place where there is much to the place where there is little. This movement can go on through liquids and moist membranes. Protoplasm uses up the oxygen brought to it, leaving very little in the cell. Therefore the oxygen passes from the blood, where it is in abundance, through the lymph to the cell. In the blood oxygen is held in chemical combina-

tion in the red corpuscle. As the oxygen in the plasma is given off, the red corpuscles undergo a chemical change, giving off oxygen to the surrounding plasma, and so keeping more oxygen in that fluid than in the lymph outside. Since carbon dioxide is produced by the activities of the protoplasm, there is always more of it in the cell than there is in the lymph and blood. As long as the cell is active the carbon dioxide flows from the cell into the lymph and blood.

In the lungs the blood containing much carbon dioxide is exposed to the air, which contains very little, and the carbon dioxide passes from the blood to the air. At the same time, the oxygen passes from the air in the lungs into the blood, because the red coloring matter in the corpuscle attracts it. It combines chemically with the red corpuscle, and can be held in large quantity.

The principles involved in this problem will be clearer if we observe their comparatively simple operation in some of the lower animals. In small, soft-bodied water· animals no special respiratory organ is necessary. The carbon dioxide goes from the cells of the animal directly into the water, and the oxygen of the air which is dissolved in the water is taken directly into the cells. In larger water animals the gases cannot readily pass between the surface and the inner cells, so there must be a fluid (blood) circulating from the interior cells

to some place at the surface where the gases can
be interchanged. This place is usually developed
just for the purpose of respiration, and is especially
adapted to that end. It is called a gill. The essen-
tial structure of the gill is a thin membrane with
the blood on one side and the air of the water on
the other. Some of the oxygen from the water
passes through the membrane into the blood, and
some of the carbon dioxide passes out from the
blood into the water. In animals which live in the
air the respiratory apparatus cannot be a gill tuft
outside the body; it would collapse and dry up.
Instead, it is a set of tubes which bring the air into
the body. In the insects the tubes run to all parts
of the body and so distribute the air directly. In
the vertebrates the air tubes are gathered into one
place, the lungs, to which the blood is brought for
the exchange of gases.

Air passages. Study Figures 37 and 38. The
pharynx is the chamber at the back of the nose and
mouth, through which both food and air pass. Its
walls are soft and loose, composed of muscle and
covered with mucous membrane. In the lower part
of the pharynx are the troublesome tonsils, which
seem to be of no use, and are commonly taken out
if they repeatedly become inflamed. In the upper
part of the pharynx is located a similar organ,
called the pharyngeal tonsil. It often becomes en-
larged in children, obstructs the nasal passage and

develops mouth-breathing.   Catarrh usually fol-
lows.   The growths obstructing the nasal passage
are called adenoids.   Since the Eustachian tube
from the middle ear opens into this region, adenoids

CEREBRUM

CORPUS
CALLOSUM

CEREBELLUM

MEDULLA

EUSTACHIAN
TUBE

NOSE CAVITY

HARD
PALATE

SOFT
PALATE

TONGUE

TONSIL

EPIGLOTTIS

PHARYNX

SPINAL CORD
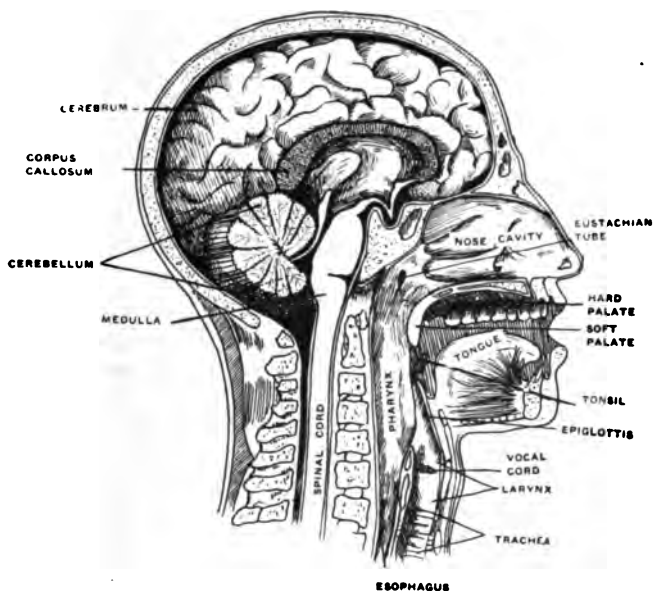
VOCAL
CORD

LARYNX

TRACHEA

ESOPHAGUS

FIG. 37.   Median section through the head and neck.

may cause deafness.   If they produce the symptoms
mentioned, they should be removed.

The pharynx is continuous below with the
esophagus, and from it the air passes through the
glottis into the larynx.   The pharynx and glottis
are open as we breath, but when we swallow the
food or water is pushed down the pharynx into the

esophagus by the contraction of the muscular walls.
This blocks the air passage. As the food comes
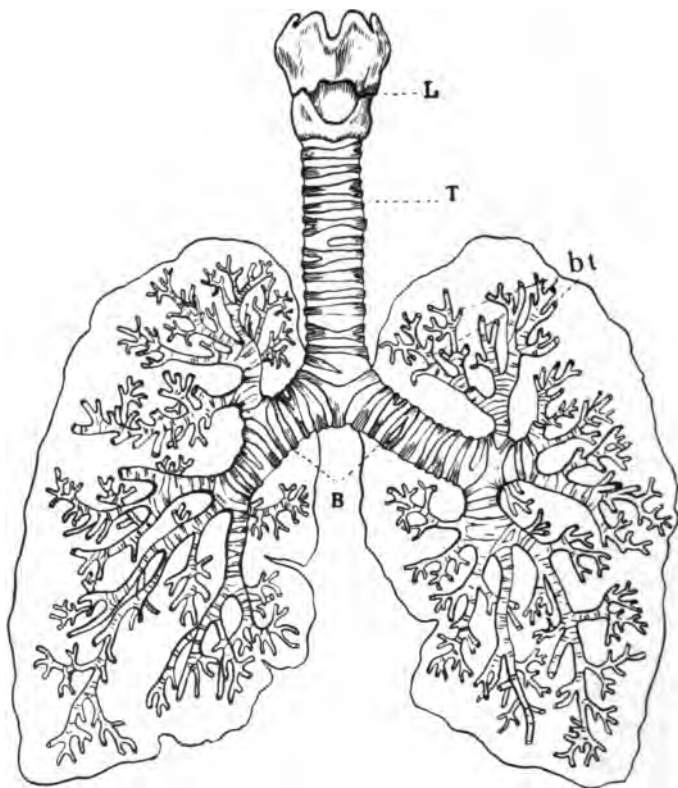into the pharynx from the mouth, the glottis is

FIG. 38.   Front view of the larynx L, trachea T, bronchial tubes
B, bronchioles bt.

closed by a lid called the epiglottis, which is folded
backward, thus preventing the food's getting into
the larynx.   Sometimes a breath through the

mouth may draw a particle of food or a drop of water into the larynx. The tender lining of this organ is irritated and a cough is reflexly set up to expel the intruding particle.

1. Is the air passage straight or crooked?

2. As the air moves through this passage, striking against the moist sides, what becomes of the dust and germs in it?

3. By what structure is the surface lining of the nose cavity greatly increased?

4. How is the temperature of the air entering the lungs affected in its passage through the nose? The air becomes nearly saturated with vapor in the nasal passage, so that it will not dry up the lungs.

5. Give three reasons why we should breath through the nose rather than through the mouth.

The larynx. The larynx is an irregular chamber whose walls are stiffened by plates of cartilage. The two vocal cords are not like violin strings, hanging free between their fastenings, but they are narrow folds of mucous membrane fastened along their whole length to the larynx frame. They are on opposite sides of the larynx, leaving a narrow slit between their edges. Small muscles change the size of this slit and the tenison of the cords, and thus regulate the pitch of the voice.

1. Feel the larynx in the neck, the Adam's apple. How long is it? How wide?

2. When you swallow what change occurs in the larynx? It is this movement that closes the glottis.

For the study of the remainder of the air passages, the trachea, and bronchial tubes, get a sheep's lungs from the butcher.

Sheep lungs. Arrange the lungs in position, distinguishing the right from the left. The ventral side has the deep division between the lobes, and the bronchial tubes branch into the dorsal part.

1. What is the general color of the lungs? Is the color uniform?

2. Blow through a tube (a test tube with a hole in the bottom) inserted into the trachea, and inflate the lungs. How does the size of the inflated lungs compare with that of the collapsed lungs?

3. Compress the collapsed lungs gently; release the pressure. Is the lung tissue elastic or inelastic?

4. When you stop inflating the lung, why does it collapse?

5. Put a lung or a piece of lung into water. Why does it float?

6. On which side, dorsal or ventral, are the cartilage rings of the trachea incomplete? Compress the trachea gently and observe the movement.

7. Compress the bronchial tubes gently; are the rings complete or incomplete?

8. Does this condition of rings prevent or make possible a change in diameter of the air tubes?

9. Describe the serous membrane covering the lungs. Is it smooth or rough? Tough or tender?

10. Describe the mucous membrane that forms the inner surface of the trachea. Is it rough or smooth, dry or moist? Compare with the outside of the trachea.

11. Do the veins and arteries leave and enter the lung

near the large bronchial tubes or at the outer margin of
the lung?

Mucous membranes. The cavities opening to
the outside of the body are lined with mucous mem-
brane. They may be thought of as infoldings of
the skin. The lining cells of the mucous membrane
are called epithelial cells. Sometimes, as in the
stomach and intestine, they are in a single layer,
like the cells of a honeycomb, and are fastened to
a basement membrane. [See Fig. 3, D, also 39.]
Sometimes, as in the mouth, they are flat and ar-
ranged in layers lapping over each other like shin-
gles. These two forms are called, respectively,
columnar epithelium and pavement epithelium.
The membrane is kept moist by a fluid, mucus,
secreted by special cells. Some digestive fluids are
also secreted by the mucous membrane, which, in
places, is folded into glands to give more secreting
surface.

Serous membranes. Closed cavities of the body,
such as the chest cavity and the abdominal cavity,
are lined with a serous membrane. The cells of the
serous membrane are flat and thin and its fibers
abundant, making the membrane strong. Although
a serous membrane produces a little fluid to keep
it moist, it is not an extensively secreting surface
like the mucous membrane. Its function is to
make smooth a surface that moves on another so
as to prevent friction.

The synovial cavity of the joint is a closed sack. It is, however, different from serous cavities, and forms a class by itself.

Cilia. The mucous membrane of the trachea and bronchial tubes, of part of the larynx and part of the nasal cavity is covered with cilia, fine threads of protoplasm which project
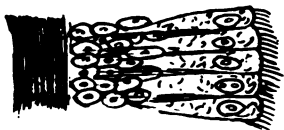

FIG. 39. Section of mucous membrane of the trachea, magnified 350 times, showing cilia on the surface of the cells.

from the surface of the epithelial cell about 1/2000 of an inch. The cilia move back and forth together very rapidly, making a wave movement like a field of wheat or oats in the wind. The waves progress

FIG. 40. Infundibulum, small divisions of the air spaces of the lung, magnified.

toward the larynx, driving along the mucus and the dust and germs that have been caught in it. When the mucus reaches the larynx it produces an irritation which provokes a cough to expel it. If it were not for this cleaning device, the lungs would soon become clogged with the dust of the air we breathe.

For how long a time after you have been in a very dusty atmosphere can you notice the black stain in the mucus from the throat?

Lobule. The smallest divisions of the bronchial tubes are about 1/50 of an inch in diameter. They end in sacks called lobules, or infundibula, which art partially divided into air chambers or vesicles, as shown in Figures 40 and 41. In the walls of the lobule are blood capillaries. [Figure 42.] The lining of the vesicles and capillary walls form the
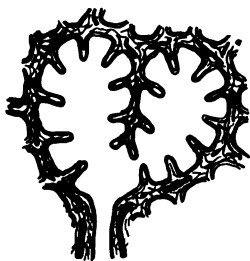

FIG. 41. Sectional view of the air sacks shown in Fig. 40. The black spots represent sections of blood vessels.

FIG. 42. Capillaries, much magnified, which lace over the lining membrane shown in Fig. 41.

thin membrane, found in all respiratory organs, through which the gases pass.

Mechanism of breathing. Things we are conscious of doing all the time, we are likely to think of as simple processes that need no explanation. When the question arises—What makes the air go into and out of the lungs?—we are inclined to answer, "We just breathe it in and out." But this is no explanation. Watch your neighbor inhale and notice your own inhalations.

The result of these inhalation movements is to

make the chest capacity greater. The air in the lungs, therefore, expands and is under less pressure. The greater atmospheric pressure without drives in more air. The muscles which cause the diaphragm to lower are in the diaphragm itself. The chest is moved upward and outward by mus-
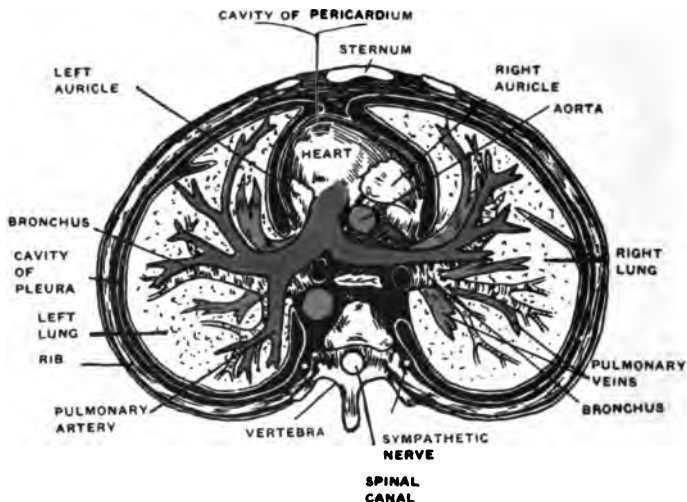

FIG. 43.   Cross section of the chest.

cles running from rib to rib, and from the ribs to the shoulders.

1. In what direction does the front of your chest move?

2. Does the movement make the chest cavity larger or smaller?

3. The diaphragm is a sheet of muscle and tendon. If it contracts, does it rise or fall? See Fig. 44. Does this make the chest cavity larger or smaller?

4. In inhalation in what direction do you observe the front of the abdomen just below the breast bone to move?

5. What motion of the diaphragm would force the abdominal walls outward? You infer that the diaphragm moves in what direction in inhalation?

6. Swing your hands up slowly till they meet as high as you can reach. How does the elevation of the shoulders affect the chest?

7. Let your body represent your backbone, your forearms represent your ribs, and your clasped hands your sternum. Should your arms slant up, or down, or extend out horizontally?

8. Raise the arms slightly. Does the motion make the space between the hands and the body greater or less?

9. How may the front of the chest be made to move forward in inhalation?

10. Study exhalation in yourself and in your neighbor. In what direction does the front of the chest move?

11. Does this make the chest cavity larger or smaller?

FIG. 44. Diagrammatic representation of the trunk, to show the changes that occur in the diaphragm and front wall during respiration. The dotted line shows the position at the end of inhalation.

12. In what direction does the upper front part of the abdomen move?

13. How does this affect the diaphragm? Does it make the chest cavity larger or smaller?

14. The diminution of the chest cavity increases the pressure of the air in it, till the interior pressure is greater than the atmospheric pressure, and some of the
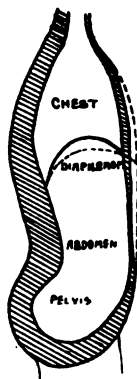
air is forced out. Is the greater muscular force ordinarily used in inhalation or exhalation?

15. Expel the breath quickly but forcibly; where do you feel the muscles contract?

16. Explain how this muscular contraction can diminish the chest cavity.

In ordinary respiration the elasticity of the lungs and of the walls of the chest is sufficient to cause the expulsion of the respired air; in forced respiration the ribs are pulled down and are swung inward partly by muscles in the abdomen and partly by muscles slanting down and back to the spine. You have already observed that when the walls of the abdomen contract the diaphragm is forced up.

The products of respiration. The air that enters the lungs is the common atmosphere,—about 79% nitrogen and argon, 21% oxygen, .03% carbon dioxide, and a variable amount of water and dust. The air exhaled contains about the same quantity of nitrogen, but much less oxygen (16%); about one hundred times as much carbon dioxide (4.38%), scarcely any dust and much water vapor. The exhaled air contains also some substances so intangible that their nature cannot be determined. They seem poisonous, and give to the ill-ventilated room its bad odor. These, or similar substances, seem to be given off by the skin also. There is no benefit in the exhalation of water vapor, but it is

impossible to expose a mucous membrane and
warm, moist blood to dry air without its evaporat-
ing considerably.

Ventilation. We could breathe in air containing
less oxygen than there is in the atmosphere and an
amount of oxygen larger than the normal is not
harmful. The red corpuscles can take only a cer-
tain quantity, and when they are satisfied the
remainder of the oxygen is simply exhaled. We
can exhale into an air having several hundred times
as much carbon dioxide as there is in the atmos-
phere, but much increase of carbon dioxide in a
room means impure air.

Experiments have recently been made to learn
just why an ill-ventilated room is oppressive. We
know that a "close" room makes one restless and
unable to work at his best. One becomes sleepy
and stupid and may even faint. It is not now gen-
erally thought that there is too little oxygen or
too much carbon dioxide in the room. But there
is considerable support to the theory that the harm-
fulness of bad air is due to substances given off by
the skin and lungs, which cause the disagreeable
odor of foul air. The most recent studies show
very clearly that most of the discomfort of bad air
is the result of its too high temperature and its
faulty humidity. Bad air, when set in motion by
an electric fan, may lose its oppressiveness. This
seems to mean that when the perspiration is evap-

orated and the skin cooled we do not suffer from poor ventilation.

Much still remains to be learned about ventilation and the most desirable temperature and moisture conditions; but we can be sure of the desirability of (a) a circulating in preference to a stagnant air, (b) enough moisture to prevent the discomfort of drying the mucous membrane of the nose and mouth, yet not so much as to retard the evaporation of perspiration, (c) a temperature not above 70 degrees for ordinary rooms. There is indeed considerable reason for thinking that a lower temperature, between 65 and 68, and possibly less than 60, is preferable to 70 degrees.

Count the number of inhalations you make in a minute, or better, since our own breathing is influenced by our thinking about it, study the respiration of your neighbor who does not know he is observed.

1. How many inhalations are there a minute?

2. If they are not all alike explain how some differ from others.

3. Count the respirations of one who has just paused in vigorous exercise. How does the number compare with the previous count?

4. The lungs take in at an average breath 30 cubic inches. At that rate, how many cubic feet would you need in a day if you were sitting still?

5. That would fill a room of what dimensions?

This does not mean that you could live all day in a room of that size without ventilation. In a short time the harmful exhalations would make the air unfit for breathing, even before the oxygen was much depleted. If the exhalations could be carried off instead of mixed with the air of the room, the roomful of air would be sufficient for the day. But since we exhale into the air of a room, we need a much larger volume of air. A room should have from 800 to 1,000 cubic feet of space for each person occupying it, and, according to some authorities, a room is considered well ventilated only when there is brought in for each person 2,000 cubic feet of fresh air every hour.

Impure air. The result of breathing impure air is often a headache and always dullness and decreased vitality. This renders one more susceptible to contagious disease, especially to diseases of the respiratory organs, such as colds, tuberculosis, and pneumonia. We do not commonly appreciate the fact that a cold is a contagious disease. It has been said that one should be ashamed of having a cold, implying that it results from careless exposure to drafts or neglect of wet feet or clothing. The exposure does cause congestion of the mucous membrane, but that is soon over if the disease germs do not establish themselves. We usually take cold by breathing the air of ill-ventilated rooms and cars, which is loaded with millions of germs from

the crowded people. Polar explorers, subject to extreme exposure but in an atmosphere free from germs, do not have colds. We should avoid, as much as possible, not copious drafts of fresh cold air, but little streams of cold air on parts of the body, wet feet and damp clothing, and more important than all, we should avoid the foul air of crowded rooms.

Pneumonia (lung fever) and tuberculosis are commonly spread through lack of good ventilation.

Besides the germ diseases there are other injuries to the respiratory organs that come through impurities in the air. The dust is not all taken out of the air as it goes through the air tubes, and some of it is carried into the lobules, where there are no cilia to remove it. There it may accumulate till it interferes with the respiration and injures the delicate membrane on which it presses. The fine coal dust in the smoke of our large cities injures the lungs of all of us. The lungs of coal miners are black with the dust they breathe and are very susceptible to contagion. If the dust is gritty, composed of minute fragments of stone or metal, it is especially harmful. Stone cutters and metal grinders are short-lived, killed by the dust of their trades. A well-ventilated shop, bringing fresh air to the workmen and carrying away harmful dust, would make these trades less dangerous. One of the most harmful occupations is glass-blowing. The work-

man compresses the air in the lungs to such an extent as to injure the delicate membrane of the lobules. Glass-blowers can work at their trade but a few years and many die of lung disease.

How to ventilate. In dwelling houses the amount of space to each person is so large that little attention is paid to ventilation. The air goes through porous walls and through the cracks about the windows and doors and thus makes it possible to live in comfort without special ventilation; but the house air is far inferior to the out-of-doors air. The most approved treatment of tuberculosis keeps the patients out of doors day and night. The fresh air that works their cure is best for well people also. In crowded tenements the air is usually laden with disease germs and other harmful substances and is deficient in oxygen. Occupants of such buildings, the great mass of the city's poor, have almost universally a low vitality and are, therefore, in large numbers the prey of lung diseases.

Most of us depend on opening the windows for ventilation. In summer when the windows can be kept wide open, this does very well for rooms that are not crowded. In winter when the outside air is cold we seldom open the windows wide enough to get adequate ventilation. A small opening at the top and another at the bottom produces a good circulation of air, the cold, heavy air coming in below and driving out the warm, lighter air above.

But this produces such a cold draft that it is objectionable. The difficulty may to some extent be avoided by a board placed on the window sill, slanting inward and upward so as to give an upward direction to the incoming cold current. The fresh air then gradually settles through the room. The best arrangement is to pass the fresh air over the heating apparatus, so that it will come into the room properly warmed. Provision must be made, also, for the removal of the foul air. If its exit is near the floor, the cooler air will be taken out, and the heating will be more economical. The greater weight of the cold air coming in is sometimes sufficient to produce a circulation, especially if the exit flue runs up to the roof beside the warm chimney. In large buildings, where the air must be distributed to many rooms through long horizontal pipes, it is usually necessary to employ a fan to drive it through the supply pipes.

Fresh air. There is one fad that never does any harm and in countless instances does incalculable good—the fresh air fad. To those in health fresh air brings red cheeks, bright eyes and vigor of mind and muscle. To the sick it sometimes brings health and happiness. The most approved treatment of pneumonia includes fresh air, even in winter when the air is bitterly cold. Tuberculous patients are kept out of doors as much as possible. They eat, read and sleep in the fresh air. Living

out of doors in cold weather implies warm clothing, so that the body is comfortable. However much our occupation compels us to work in a room whose ventilation is poor, there is no excuse for our sleeping in a close atmosphere. The best plan is to sleep on a porch or under a tent, with the fresh air circulating around us. If this is not convenient, we can close our room door in winter to avoid cooling off the remainder of the house, put on sufficient blankets to keep us warm, and open the windows to let in the fresh air,—not an inch at top and bottom, but wide open so that the air may circulate freely around us.

In some schools the children who are tuberculous, and those who have a low vitality, are put in fresh air rooms with the windows open. In cold weather suitable clothing keeps them warm. These children usually show a wonderful improvement in health as well as marked progress in their studies. Fresh air rooms for children in health seems equally successful. The pupils do better work and are almost altogether free from the colds which afflict pupils in other rooms.

1. Explain the method by which your school room is heated and ventilated.

2. Is there any special ventilating arrangement in your house? If so explain it.

Drugs. Several stimulants and narcotics have a marked temporary effect on the respiration. In

general, stimulants increase the rate of respiration, while narcotics diminish it, though there are exceptions to this. The habitual use of drugs produces serious injury to the respiratory organs. People addicted to the use of alcohol are more subject to pneumonia and asthma than are others, while smoking injures the mucous membrane of the mouth, nose and throat. A cancer of the tongue not infrequently results from smoking a pipe.

FOODS

Our need of food. We need food for two purposes: First for growth, and second for the repair of tissues worn in doing work and producing heat. For the first purpose, foods must supply the elements which are in protoplasm, and foods used for the second purpose must contain a large amount of carbon, since most of the energy of the body is produced by the oxidation of carbon. It is not sufficient that the food simply contain the necessary elements, but the elements must be in such combination that the protoplasm can build them into its own structure. From the soil, plants take water (H_2O), nitrates (KNO_3), potash salts (KCl), etc., and from the air, carbon dioxide (CO_2). They combine these substances into protoplasm. (Do these raw materials contain all the chief elements of protoplasm?) Animals cannot do this. They must take their food from plants or from other animals in the form, or almost the form, in which it enters into chemical combination in their protoplasm. Our food, then, is composed of elaborated compounds obtained from other animals or from plants. There are three classes of foods.

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Nitrogenous foods. The element nitrogen is present only in certain food substances. They are called nitrogenous foods. All protoplasm of plants and animals, when it dies and is used for food, is included in this class; and since every piece of the plant or animal (except dead parts like old wood, hair, etc.) contains some protoplasm, we get more or less nitrogenous food in all we eat. Besides protoplasm there are a number of other nitrogenous food substances in both plants and animals, such as gelatin or the gluten in wheat. Our most common nitrogenous foods are all kinds of meat, except fat, the curds of milk, cheese, eggs, gelatin; among the vegetables, peas, beans and lentils; and all kinds of cereals except rice.

Carbohydrates. Carbohydrates are composed of only three elements, carbon, hydrogen and oxygen. Common sugar is expressed by the formula $C_{12}H_{22}O_{11}$, grape sugar by $C_6H_{12}O_6$, and starch by $n(C_6H_{10}O_5)$. The "n" means that the starch molecule is not just the 21 atoms indicated, but a certain number, perhaps 20 or more, times the 21 atoms. Notice the amount of hydrogen compared with that of oxygen in the carbohydrates. Sugars and starches are the chief carbohydrate foods. Most of the sugar we use comes from the root, stem or fruit of plants. Milk is about 3% sugar.

1. Name a root that supplies a large per cent of the world's sugar.

2. Name two plants whose stems supply sugar for our markets.

3. What commercial sugar comes from a fruit or seed?

Starch is the main food of the human race. It comes from nearly all parts of plants: wheat, corn and rice are seeds; sago is from a stem; potatoes are underground stems; sweet potatoes are roots. Figure 45 shows the arrangement of starch and proteid (nitrogenous material) in beans and potatoes. In many plant cells the only nitrogenous matter is a small amount of protoplasm, nearly all the cell contents being starch. In peas, beans and lentils, however, most of the nitrogenous matter is not protoplasm, but a stored proteid, and composes about one-fourth of the whole seed. The vegetable cell wall is woody material (cellulose) almost like starch. Some animals can use it for food, but in the human body it seems to be indigestible. The cellulose serves
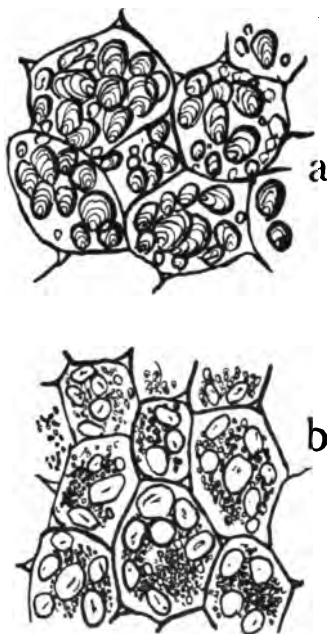

FIG. 45. a—Cells of the potato, filled with starch. b—cells of the bean, filled with large starch grains and small proteid grains.

a useful purpose, however, in giving bulk to the food.

Fats and oils. Like carbohydrates, fats and oils are composed only of carbon, hydrogen and oxygen. They vary more in the ratios of the elements, and have a lower percentage of oxygen than do the   .
carbohydrates.

1. Name as many animal fats as you can that are used for food.

2. Name as many vegetable oils as you can that are so used.

3. At the usual atmospheric temperatures are the common animal fats solid or liquid?

4. In which condition are the vegetable oils?

Using the following methods, test as many as you can of the food substances that come into the kitchen, to find out what kinds of food each contains:

A. In a test tube containing a small quantity of strong nitric acid boil a bit of food for a few seconds. Be very careful not to get the acid on your hands or clothes. Drain off the acid and add enough ammonia to the food to neutralize it. If nitrogenous material is present it turns orange color.

B. Add enough iodine crystals to a water solution of potassium iodid to give it a light brown color. Put a drop of this solution on some starch and observe the color you get. Find out whether raw starch or boiled gives the brighter color.

C. Haynes' solution is used in testing for sugar. To make it, completely dissolve 30 grains of pure copper sulphate in ½ an ounce of pure water (warm a little if

necessary), mix thoroughly with ½ ounce of pure glycerine, add 5 ounces of liquor potassae (5% solution of KOH). In a test tube boil a little of this solution into which you have dropped a bit of the food to be tested. Try first some pieces of raisin or other sugary fruit. The red color you get is caused by the grape sugar. Boil a solution of cane sugar in 1/10 its volume of strong sulphuric acid before testing; this changes it to grape sugar.

D. Put on a piece of paper, such as filter paper, a tiny drop of oil and in another place a drop of water, and observe the characteristic translucent mark oil makes. Then rub on the paper a bit of food to see if it contains fat or oil.

Test a piece of cabbage, of turnip, of bread, of meat, of egg—as many things as you can—by each of these four methods, and list the kinds of food found in each. The following is a convenient form for making your record:

FOOD CONSTITUENTS

Food Substance	Nitrogenous	Sugar	Starch	Fat
Milk, etc.	Found	Found	Not found	Found

Sometimes you will be able to write not simply "found" or "not found," but whether the quantity is much or little.

Inorganic foods. There are in the body certain salts not included in the classes of food given above. Most of them are taken incidentally with the various foods and with the drinking water. Only one, common salt, do we add to our diet intentionally. In ordinary drinking water we get much

more calcite (lime salt) than we need, sometimes more than is good for us. Potash is in most vegetables. Lean meat contains about all the salts we need.

Energy foods. Though energy is liberated by the oxidation of any food, the fats and carbohydrates are especially suited to supply energy, and are therefore often called the energy foods. While all foods are perhaps changed into the protoplasm in preparation for its down-breaking in the liberation of energy, the nitrogenous foods alone can supply all that is needed for the repair and growth of protoplasm. They are therefore called the food for growth and strength.

COMPOSITION, ENERGY VALUE AND COST OF FOODS

Food, as purchased.	Refuse.	Water.	Protein.	Fat.	Carbohydrate.	Ash.	Calories per pound.	Price, cents, per pound.	Calories for one cent.
Beef loin........	13	52	16	17	...	.9	1,025	....	....
Veal, leg cut....	3	68	20	7	...	1.0	695	....	....
Mutton loin.....	16	42	13	28	...	.7	1,415	....	....
Pork loin.......	20	42	13	24	...	.8	1,245	....	....
Salt pork.......	..	8	2	86	...	3.9	3,555	....	....
Tomato soup....	..	90	2	1	6	1.5	185	....	....
Fowl	26	47	14	12	...	.7	765	....	....
Halibut steak...	18	62	15	4	...	.9	475	....	....
Oysters (solid).	..	88	6	1	3	1.1	225	....	....
Eggs (hens')....	11	65	13	9	...	.9	635	....	....
Butter	..	11	1	85	...	3.0	3,410	....	....
Whole milk.....	..	87	3	4	5	.7	310	....	....
Cheese (cream).	..	34	26	34	2	3.8	1,885	....	....

COMPOSITION, ENERGY VALUE AND COST OF FOODS—*Continued*

Food, as purchased.	Refuse.	Water.	Protein.	Fat.	Carbohydrate.	Ash.	Calories per pound.	Price, cents, per pound.	Calories for one cent.
Wheat flour......	..	12	11	1	75	.5	1,635	....	....
Corn meal.......	..	12	9	2	75	1.0	1,635	....	....
Oats (br'kfast).	..	8	17	7	66	2.1	1,800	....	....
Rice	..	12	8	.3	79	.4	1,620	....	....
White bread.....	..	35	9	1	53	1.1	1,200	....	....
Sugar	..	..	....	....	100	...	1,750	....	....
Beans (dry).....	..	13	22	2	60	3.5	1,520	....	....
Beans (string)..	7	83	2	.3	7	.7	170	....	....
Cabbage	15	78	1	.2	5	.9	115	....	....
Onions	10	79	1	.3	9	.5	190	....	....
Potatoes	20	63	2	.1	15	.8	295	....	....
Sweet potatoes..	20	55	1	.6	22	.9	440	....	....
Tomatoes	..	94	.9	.4	4	.5	100	....	....
Apples	25	63	.3	.3	11	.3	190	....	....
Bananas	35	49	.8	.4	14	.6	260	....	....
Grapes	25	58	1	1	14	.4	295	....	....
Strawberries	5	86	.9	.6	7	.6	150	....	....
Raisins	10	13	2	3	68	3.1	1,265	....	....
Peanuts	24	7	19	29	18	1.5	1,775	....	....
Walnuts (Eng.).	58	1	7	27	7	.6	1,250	....	....
Chocolate	..	6	13	49	30	2.2	2,625	....	....

The amount of energy yielded by oxidizing a pound of food is expressed in the heat units (calories) column. The carbohydrate column is mostly starch, but is altogether sugar in milk and in small part sugar in most of the foods given. The data of this table is given somewhat differently by different authorities. The figures here given are on the authority of United States Department of Agriculture.

Fill in the cents per pound column with the prices of your markets (eggs 1½ pounds per dozen, apples 12 pounds to the peck, potatoes 15 pounds to the peck, three or four bananas to the pound). Then reckon from that and the heat units column the amount of energy yielded by a cent's worth of each kind of food.

1. In which food do you buy the most energy for a cent?

2. In which food do you buy least?

3. What do you think is the reason that starch is man's chief food?

4. Which kind of food yields the largest amount of energy per pound?

5. Which food yields least energy per pound?

6. Why do people in very cold climates eat so much fat?

The use of a food as an energy supplier depends upon its digestibility and upon the character of the waste substances that result from its oxidation. The carbohydrates are easily digested, and they oxidize to water and carbon dioxide. The carbon dioxide is easily removed from the body through the lungs, and the water is useful in the body. The wastes from the oxidation of nitrogenous foods are more complex and much more difficult to remove. Therefore, from both financial and physiological considerations, the fat and carbohydrate foods are the most economical sources of energy. We must not, however, choose our food altogether accord-

ing to its energy value. It is well for us to take
enough fat and carbohydrate food to supply the
energy required for heating the body and for doing
our work. But we must have nitrogenous food
sufficient for growth and for the repair of the body.

1. Ignoring the water, what food in the table shows
a per cent of nitrogenous material large in comparison
with the other constituents?

2. From what foods would a vegetarian get his nitro-
gen supply?

Quantity. How much food of each kind one
needs in a day depends so much on the age, size
and activity of a person that no amount can be
given that will just meet the requirements of even
a majority of people. Each one must find out by
experiment what he needs. The appetite is not an
altogether reliable guide, because it is largely a
thing of habit, and it is satisfied with quantity
rather than quality. If we eat less than the custo-
mary amount, though we may have taken sufficient
for the needs of the body, the appetite calls for
more. Growing boys and girls, living much in-
doors, often eat too little; others too much.

If the body is to lose nothing of its weight and
from its possibilities for work, it must receive as
much energy in its food as it uses up in its work.
In some experiments the quantity of work done in
a day has been expressed in units of energy, so that
the amount of food-energy needed is known. But

such special experiments are of slight value to people engaged in the varied pursuits of common life, and how much of the food should be nitrogenous and how much fat or carbohydrate is not so easily determined. An ideal ratio is given by one physiologist as 18 per cent nitrogenous, 8 per cent fat and 74 per cent carbohydrate. If one has difficulty in digesting fat he should decrease the amount of fat and increase correspondingly the amount of carbohydrate.

Variety. A strong, healthy person does not need to pick and choose his food; he can thrive on any of the foods commonly used by man. If the quantity and quality do not depart too far from the ideal standard, he will get along very well. Of course, he cannot work and keep strong on a deficient diet, and a monotonous diet is likely to be deficient in certain things and to contain too much of others. Therefore, a varied bill of fare is more likely to give a better balanced ratio. If there is plenty of nitrogenous material and plenty of fat and carbohydrate, the body can take what it needs of each and let the superfluity alone, or from the excess fat can be produced and stored. Variety appeals to the taste, also, and it is always desirable to stimulate digestion by enjoying the taste of food. We can live on a wholly vegetable diet or on an exclusively meat diet, but a mixed diet is better balanced. Vegetarians, especially if they do not use

milk, eggs or cheese, need to exercise care in selecting foods containing salts and nitrogen—the most important constituents we get from flesh foods.

1. From the table on page 134 choose the foods that have a high per cent of tissue-building (nitrogenous) substance.

2. If the water were eliminated from lean meat and peas how would they compare in the amount of proteid?

3. What part of potatoes and cabbage would be proteid if the water were taken out?

Condiments. Pepper, mustard and spices are often put into the food to make the taste more attractive. They are called condiments. In that they stimulate the digestive organs, they may be of use in the process of digestion. But most of the condiments irritate the mucous membrane, and, like other stimulants, if they are taken habitually and in considerable quantities, they lose much of their effect, and the organs do not work well without them. If used strong, the condiments dull the taste so that delicate flavors cannot be appreciated. Use them sparingly.

STIMULANTS AND NARCOTICS

A stimulant is something which increases the activity of the body or of a part of the body, and a narcotic is something which decreases the activity of the brain. By an increase in activity we mean that the chemical changes which occur in the cell, such as oxidation, are more rapid, and, consequently, the work done by the cell is greater. This requires more blood, which is supplied sometimes by an increase in the rate of the heart beat, sometimes by a stronger contraction of the heart, sometimes by enlargement of the blood vessels that supply the part stimulated, and sometimes by a combination of these methods. Alcohol, tea, coffee, nitro-glycerine, strychnine, belladonna, and many other drugs are stimulants. After the stimulating effects of some of these drugs, such as alcohol and belladonna, are passed, a narcotic effect follows which may be profound if the dose is large. A man stupefied by liquor is in the narcotic stage. Some narcotic drugs, as opium and hasheesh, have a noticeably stimulating effect at first. These complicated effects result in some confusion in classifying drugs, but if the stimulating effect is

conspicuous, as in alcohol and coffee, the drug is usually called a stimulant, while the term narcotic is given to those drugs whose chief effect is to retard action, as opium and tobacco. The confusion is made worse by the fact that one part of the body may be stimulated while another part is narcotized by the same drug. Cocaine, for example, deadens the local nerves of sensation while it stimulates the motor activities. Most stimulants and narcotics when taken in large doses are poison. In suitable dosage, however, they are valuable drugs; but they should be used only by those who understand their effects and will use them wisely.

The harm in stimulants and narcotics comes from the habitual use of drugs that change the normal physiological activities. The body seems to be elastic in its activities. By introducing some artificial conditions you can force it out of its normal course of action, and when you remove your interference, it springs back to its regular activities. But if the interruption is repeated frequently, especially while the body is still immature, the elasticity is overstrained and the body does not perfectly recover its normal functions. Stimulating and narcotizing drugs are such intrusions upon the normal physiological activities of the body. Taken occasionally in very small quantities, they produce abnormal conditions from which the body seems to recover easily. They may then be used as medi-

cines to meet occasional abnormal conditions of
the body. But taken habitually, especially in con-
siderable quantities, they produce lasting derange-
ment of our functions. When the body becomes
accustomed to a stimulant or narcotic, it fails to
respond to a small quantity of the drug, so larger
doses must be used. These quickly bring serious
consequences. One accustomed to the use of a
stimulant feels nervous and craves it, and is unable
to work well when he lacks it. When he has a
little he wants more and is not satisfied until he has
taken a harmful quantity. Therefore, all stimulants
and narcotics should be used with great care. The
following paragraphs discuss several of the stimu-
lants and narcotics commonly used.

Tea. You know that tea is the leaf and tender
shoot of a bush which grows in warm countries.
Most of that which we use in America comes from
China, Japan, or India, though the plants grow in
other countries and can be cultivated in our own
southern states. The leaves are not simply dried;
they must be slightly fermented, then rolled and
afterwards dried by heat (fired). This requires a
good deal of attention, so the countries that have
cheap labor trained to the work supply the world's
market. The stimulating substance in the tea is
called caffein. It is dissolved out of the leaves by
boiling water. There are also in the leaves other
substances which are extracted by boiling. One of

these, tannin, has a bitter taste. Tannin, obtained
from the bark of trees, is used in making leather.
If the tea leaves stand but a minute in boiling
water, very little of the tannin is extracted, but if
the leaves are boiled or the hot water stands long
on them, a decoction is produced which is harmful.
Tea topers might almost be said to tan their stom-
ach lining. Caffein, in the small doses taken in
occasional cups of tea, is such a mild stimulant that
no injurious effects are commonly noticed. But the
excessive use of tea, especially if it is made strong,
is to be deprecated.

Coffee. Coffee is the seed of a pulpy fruit which
grows on a small tree in tropical countries. Most
of the world's supply comes from Brazil. The
seed is cleaned from the pulp and then "cured," a
process of fermentation and drying. The stimu-
lating substance in coffee is practically the same as
that in tea, caffein. Americans are more often
intemperate in the use of coffee than in the use of
tea, and are therefore more often injured by it.
Also, it is commonly made much stronger than tea.
The use of coffee by children is especially objec-
tionable. Boys or girls who have become so accus-
tomed to the effect of coffee in the morning as to
feel the lack of it, ought to be aroused to the injury
they are doing themselves in relying upon a stimu-
lant instead of upon simple wholesome nourishing
food.

Cocoa and chocolate. Much the same kind of stimulant (theobromine) as that in tea and coffee is found also in cocoa and chocolate, but in very small amount. Aside from the sugar and cream, there is very little food in a cup of tea and not much more in coffee, while cocoa and chocolate are nearly all food. The practice of preparing the chocolate and cocoa with a large quantity of milk and sugar makes them foods instead of stimulating drinks, and there is little danger of taking so much of them as to be injured.

YEAST CELLS

FIG. 46. Yeast cells, highly magnified. They are but little larger than bacteria.

Alcoholic liquors. When we speak of stimulating drinks, we usually mean alcoholic liquors. Common alcohol is produced by yeast growing in a solution containing sugar. The sugar is chemically changed to carbon dioxide and alcohol. A wood alcohol is manufactured from cellulose, the woody part of plants. It is used for fuel, but never for medicinal purposes. It is a poison. The alcoholic liquors may be classed as follows:

A. Simply fermented liquors. These are made by fermenting the extracted juices of fruits, as cider from apples and wine from grapes. The fresh juice contains no alcohol, but it does hold in solution sugar and nitrogenous foods. The nitrogenous substance is in part used up by the growing yeast, and the sugar is changed to carbon dioxide

and alcohol. The liquor, then, contains less food than did the fresh juice, but the alcoholic stimulant has been added. The fresh juices may be bottled boiling hot and so preserved without fermenting. The simply fermented liquors contain from five to ten per cent of alcohol in the light wines, and up to 15 or 17 per cent in Madeira and Sherry. Such wines are "fortified" by the addition of alcohol. Champagne is heavily charged with carbon dioxide, which makes it fizz. Koumis is fermented milk.

B. The brewed liquors. Beer, ale and porter are brewed liquors. They are made from grains, mostly barley, instead of from sugary fruits. The grain is first malted. In this process it is soaked in water, then kept on a warm floor about three days till it has sprouted. In the sprouting of the seed, part of the starch is changed to sugar. The sprouted grain is quickly dried in a kiln, and is called malt. Malt is a rich food. In the process of digestion starch undergoes a change practically like that of malting. Malt, therefore, is partly digested starch together with a considerable amount of dried protoplasm and wood. In brewing, the malt is ground and boiled to extract the nourishing substances. Hops and various flavoring materials are put into the brew. The liquid is drawn off, cooled, stocked with yeast and put into vats to ferment at a temperature of 38 to 40

degrees,—too cool for putrefactive bacteria to grow. The growing yeast does not consume all the food material in the malt; what remains makes beer a slightly nourishing drink. Yet the nourishment costs many times as much as would the same amount of energy in common foods, and its value is more than counterbalanced by the harmful effects of the alcohol. The alcohol in some beers
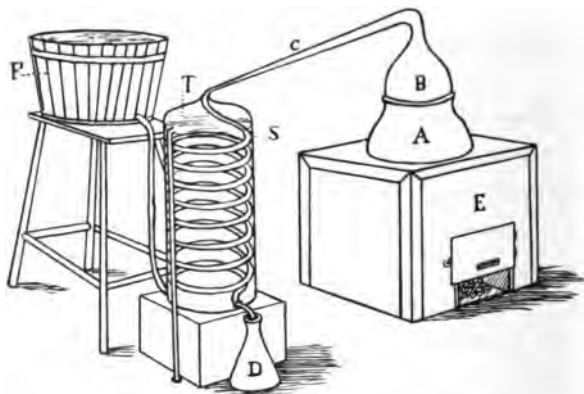

FIG. 47. A still. A and B—retort, S—worm in T—cooling jacket, E—furnace, F—water for cooling jacket.

is as low as two or three per cent, but in others is as high as six or seven per cent.

C. Distilled liquors. Distilled liquors contain a large amount of alcohol, usually 35 to 50 per cent. The process of distillation is essentially as follows:

Some alcoholic liquid, say wine, is put into a still, a tight metal vessel, and heated gently. The alcohol evaporates much faster than the water in the

wine. The mixed vapors of alcohol and water are conducted through a coiled tube called the worm, which is kept cool by a water-jacket. The vapors going through the cool worm are condensed and trickle out of the still as a liquor containing much less water than was in the wine. This liquor may be redistilled as many times as desired, each time leaving in the still some of its water, and so becoming stronger. The distillate of wine is brandy or cognac. Rum is distilled from fermented molasses. Corn and rye are malted and fermented and afterward distilled to make whiskey. The Japanese make saké from rice. A sort of whiskey is made from potatoes in northern Europe. Gin is whiskey in which juniper berries have been soaked. Substitutes for juniper berries are often used.

D. **The liqueurs.** Various flavoring substances are mixed with dilute alcohol to make liqueurs. They are usually strong, often stronger than whiskey and brandy. Absinth is one of the liqueurs; it is made from wormwood, alcohol and water.

The use of alcoholic liquors. The brewed liquors are used fresh, but wines and whiskeys improve with age. The last are not considered fit for medicinal purposes till they have been kept at least six or eight years in oak casks. Commercial alcohol, 95 per cent pure, is made by several times redistilling the fluid obtained by malting and fermenting corn and other grains. Or it may be

made from potatoes or other starchy or sugary substances. It is a strong antiseptic and has many important uses in the arts. Wood alcohol is a rank poison, but it is an economical substitute for common alcohol for purposes such as burning, or for mixing shellac.

Effects of alcohol. The physiological effects of alcohol differ with the quantity used. Alcohol is oxidized in the body and thus plays the part of food in supplying energy. But it does this no better than sugar and starch do; it costs many times as much, and it has a harmful drug effect in addition to its food function. Some physicians think it valuable as a food in certain diseases, but it is used much less than formerly, and for people in health it should never be used as a food.

In general, the first effect of a small dose of alcohol (for an average person, less than an ounce of whiskey) is stimulating. The heart beats become stronger and more rapid; the capillaries are dilated, especially in certain parts of the body, as the skin, the mucous membrane, and the brain. This makes thought and movement more sprightly. The narcotic after-effects of such a small dose are distinctly noticeable. When taken in larger quantities, the stimulating effects are more transient; that is, the conspicuous narcotic effects follow more promptly. The higher activities of the brain are the first to succumb to the narcosis; the judgment is impaired;

the victim of the drug talks nonsense, and does
things of which, in sober hours, he is ashamed.
Then the muscular control is weakened; he is
unsteady in walk. The senses also are dulled; the
sight is confused; the pain of injuries is less acute.
With the increase in the quantity of drug taken,
narcosis becomes progressively more profound till
it becomes a stupor in which nearly all the activi-
ties are suspended. The respiration becomes
labored, the heart-beat slow and irregular, and
death ensues if the quantity of alcohol is sufficiently
large.

The effect of alcohol, taken in almost any ordi-
nary quantity, is to gorge the small vessels of the
skin with blood. If this is frequently repeated, the
vessels become permanently enlarged, and the
blood flows through them slowly, turning dark
from its loss of oxygen. This accounts for the red
and purple noses and cheeks of old topers. Other
causes may produce similar effects in the appear-
ance of the skin; the depressed circulation of
elderly people usually shows in the skin of the face

A small amount of alcohol stimulates the secre-
tion of saliva and of gastric juice, and is therefore
sometimes prescribed, usually in the form of bitter
brewed liquors or light wines, as an aid to diges-
tion. However, it loses its efficiency, as does any
other stimulant, when used habitually. In larger
doses, the mucous membrane lining the stomach is

seriously injured, and the digestive functions are otherwise impaired.

You know that athletes in training do not use alcoholic drinks. They want their muscles to develop as fully as possible. This is best accomplished with simple, nourishing food. Alcohol would interfere with the nutrition as well as with the contraction of the muscles. The interference of alcohol with the perfect nutrition of the body is most marked in the young, where the rate of growth depends so much on the quantity of food assimilated. Experiments with animals show that those given alcohol with their food do not grow so rapidly nor so large as those given nourishing food only. The practice of letting children sip from their parents' beer or wine glass cannot be too strongly condemned.

It is often said that the beer used by the Germans is a harmless, even beneficial, drink. True, it does contain nourishing substances and only a small per cent of alcohol; and there seems to be in Germany less intoxication than in America. But the beer users suffer heavily from their drinking. The quantity of beer used is often enormous; the body is overloaded with water, to get rid of which the kidneys are overworked and almost always become diseased. Then the constant irritation of small quantities of alcohol produces degeneration of the liver. The abdomen becomes distended, and

dropsy is of frequent occurrence. Not the least of the evils of beer-drinking is over-nourishment. In general beer drinkers are likely to become far too fat, and, like fattened animals, they have little inclination to muscular activity and still less to mental activity.

The excessive use of alcohol is responsible, more than that of any other drug, for serious derangements of various organs as well as the general breakdown of the whole body. The nervous system is the greatest sufferer. Weakness, tremor, morning headaches and disinclination to work without stimulants become habitual. Insanity is a frequent outcome. A slight shock or injury or a prolonged spree may end in delirium tremens, a state of continuous mental and muscular activity, which often terminates with heart failure and death. The nerve trunks may be affected, producing terrible pain and even paralysis. The muscles become wasted under the influence of alcoholic excess. While the beer drinker is fat, the whiskey toper often becomes emaciated. His artery walls lose their elasticity. Breathing is difficult. The stomach becomes inflamed and its digestive power is seriously impaired, if not quite destroyed. You must not think that this whole list of ills is visited upon everyone who violates the laws of temperance, yet comparatively few people persist many years in the excessive use of alcoholic liquors with-

out falling a prey to some of these messengers of retribution.

Opium. When dried, the milky juice that oozes out of scratches made in the green seed pod of the poppy becomes opium. Laudanum is a tincture (alcoholic extract) of opium, and morphine and codeine are white powders made from the same drug. All these drugs have great value in medicine, and all have been woefully misused. They so thoroughly benumb the senses that they come as a great boon to those suffering prolonged pain. They bring such prompt and thorough relief that the sufferer is tempted to employ them again and again, till their use becomes a habit. The body becomes accustomed to the use of the drug, craves it, and is miserable when it is lacking. The opium drugs have at first a slightly stimulating effect which is quickly followed by a pleasant, and often blissful languor said to be filled with charming dreams. In large doses, the drug so depresses the vital activities that the heart-beat and respiration become very slow, and, in overdoses, they stop altogether. Under the habitual use of these drugs, the tissues of the body fail to assimilate sufficient nourishment, and rapidly waste away. The secretion of digestive juices is decreased, the blood is impoverished, the face is pale, the pupils dilate except when under the influence of the drug, headache, dizziness and tremor are frequent, the victim

of the drug becomes a moral and physical wreck,
and only by the most strenuous determination and
careful treatment does he recover. The opium
drugs are especially poisonous to children. Infants
have been killed by doses so small as hardly to
affect an adult. Some soothing syrups contain
opium, and for this reason should be carefully
avoided. The opium drugs should never be given
except on a physician's order.

There are other drugs valuable for their power
to stimulate special organs or to deaden pain or
bring sleep. Several of them are occasionally mis-
used, as are alcohol and opium, to the pitiable ruin
of their victim. Cocaine and chloral are of this
number. We should remember that all these stim-
ulants and narcotics are drugs, not food and drink,
that they produce abnormal activities in the body,
and that their legitimate function is to meet other
abnormal conditions. The physician, the one who
understands both the disease and the effect of the
drug, is the only proper person to prescribe the
medicine. Taken only occasionally and in very
small doses, some of these drugs may produce no
deleterious effects that can be noticed, but as they
are used by those addicted to them, they are not
simply harmful but ruinous.

Tobacco. Tobacco is the leaf of an herb that
grows in temperate and warm climates. It is used
chiefly in three ways: for smoking, for chewing,

and as snuff. Though it is often used pure, it is frequently mixed with substances which modify its flavor but have little physiological effect. The active drug in tobacco is called nicotine. It is a deadly poison. The reason the users of tobacco do not experience the poisonous effects of the drug more than they do, is because they get such exceedingly small quantities of it. Most of the nicotine is puffed out with the smoke. Smokers begin by using only small quantities of tobacco, and by the time they come to use it freely, their bodies have become accustomed to the drug.

The body can become accustomed to almost any poison by taking small doses at first and gradually increasing them. In time a dose can be easily endured which at first would have been fatal. The poison that is tolerated by the body accustomed to it is by no means harmless. Though it does not produce the characteristic toxic effects, it injures the body in more subtle ways. Tobacco is one of such poisons. If taken the first time in consider-able quantity, it shows its poisonous nature; vio-lent vomiting and headache ensue. Many people begin to use the drug so gradually that they never feel these toxic effects, and others seem to have a natural tolerance for the drug (as many people have for other poisons) so that the moderate quan-tity used never seems to affect them seriously. Nicotine, as used, is a mild narcotic. It dulls the

sensibilities, renders nervous people somewhat
easier in mind and inclined to languor. This dead-
ening of the nerves brings its retribution in time.
You may see on the streets and in the business
houses of any city hundreds of men who are unable
to hold their hands steady, because their nerves
have been ruined by cigars.

The heart is especially susceptible to the influ-
ence of tobacco, as well as that of tea and alcohol.
Young people are more likely to suffer from
"tobacco heart" than are their elders. Boys are
sometimes rejected from athletic contests and from
occupations requiring a vigorous physique because
their hearts show the evil effect of tobacco. If the
heart of a boy is injured by smoking, it may, on the
cessation of the evil practice, regain its normal
activity; but sometimes it becomes permanently
enlarged and weakened, even to a dangerous
extent. It is impossible to say how many of the
heart failures are due to the excessive use of
tobacco.

Headache powders. There are a number of
drugs (antikamnia, orangine, bromo seltzer, etc.)
much advertised and extensively used as cures for
headache. Nearly all of them contain acetanalid,
a strong heart depressant, a dangerous drug. Sin-
gle doses have produced death. Taken frequently
by people who often have headache, it produces
characteristic disorders of the circulation. Head-

ache is a result of faulty living. We should check it by improving our hygiene. Dosing with drugs is a poor expedient. If medicines are used, it should be only on the advice of a physician.

The effects of all the stimulants and narcotics are too subtle to be fully stated in precise changes in the structure or function of any of the organs of the body. We see their effects partly in the bodily derangements and partly in the changes in the general moral tone of their victims—which is perhaps but the expression of more subtle bodily functions. We do not mean to say that a cup of tea, a glass of wine, or a cigar will impair the moral fiber of anyone, but it is a common thing to notice moral degeneration in those who habitually use stimulants and narcotics. The fine edge of courtesy is more than blunted in the man who complacently puffs cigar smoke into the atmosphere which his neighbor must breathe. Whether this moral dullness is a physiological effect of using the drug, or whether it is merely the failure to appreciate the iniquity of a customary thing, who can tell? The nastiness of chewing and snuffing has driven these practices from polite society, so we less often have occasion to observe their effects on the moral sensibilities of those who indulge in them.

People addicted to the excessive use of alcohol and opium are pretty sure to show extreme moral degeneration in time. Their regard for truth and

honor vanishes· before their craving for the cus-
tomary drug. Reduced to extremity, they feign
sickness, lie, beg, steal,—do almost anything to get
the means of satisfying their desire. The sure way
never to be brought to this condition is never to
use the drugs except on the prescription of a con-
scientious physician.

We have tried in the preceding pages to show
you something of the terrible results which come
from the misuse of some common stimulants and
narcotics. We should avoid these drugs because
we justly fear their power for evil. But there are
other reasons for abstaining from them. Consider
the millions of dollars spent each year for tobacco,
the hundreds of thousands of acres of the best land
devoted to its growth, the thousands of men, boys
and girls engaged in its manufacture (a very
unhealthful occupation)—can we afford to waste
so much when there is such great need of money
for necessities, of land for raising wholesome food,
of workers to produce useful things?

A still greater waste is the drink bill. A larger
number of acres is given to raising the materials
for its manufacture, a stronger army of laborers
working to produce the liquors, and thousands
more ruined by the beverage. We squander our
materials, waste our energies and benumb our
powers in that which harms but does not satisfy.

And yet the world is full of great things to do.

There are barren lands to clothe with forest and field, marshes to drain, canals to dig, works of art to make, magnificent cities to build, founded not on the bones of the weak and oppressed, but firmly grounded in equality and justice. This work cannot be done by people whose delight is in tickling their senses with drugs. It is a labor for strong men and women. We are summoned to mighty deeds. We must employ every resource we have, use every ounce of energy we possess, to respond to the call. We must go into training, as an athlete for a contest, nourish our bodies with the most wholesome food, discarding that which is harmful or questionable, and make us strong for the conflict. The day of heroes is not past. Choose a worthy object for your life work, put yourself in training for it, and you will have nothing to fear from stimulants and narcotics.

DIGESTION

At the beginning of this chapter we must consider the problem of what is accomplished by the digestive process, and why this action is necessary.

We have seen that food is brought to the cell by the blood and lymph. There must then be some way in which the food can get into the blood. It cannot go through the skin, for that is too thick; so we have a digestive tract, a tube with very thin walls extending through the body. But the walls of this tube are tight; there are no openings for the passage of food. Liquids, however, can go through the pores of tight membranes. Therefore, the food, to get through the walls of the digestive tract, is brought to a liquid form. Digestion dissolves or liquefies the food. Some foods, though liquid and capable of being taken into the body and carried about by the blood, are not in such chemical form that the protoplasm can assimilate them. Therefore, they must be changed into a form that is suitable for assimilation; and this work, also, is to a large extent done in the digestive organs. Common sugar, for example, is soluble, but is changed in digestion into a different kind of

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sugar more acceptable to the protoplasm; and milk, already a liquid, undergoes digestive changes before it goes into the blood.

Digestive activities. The digestive activities are mechanical and chemical. Mechanically the food is chewed or rubbed into small fragments, and these are dissolved; or, if they cannot be dissolved, they undergo chemical changes till they are soluble. Such changes are accomplished by fluids called enzymes, which by their presence cause the foods to undergo certain fermentive changes.
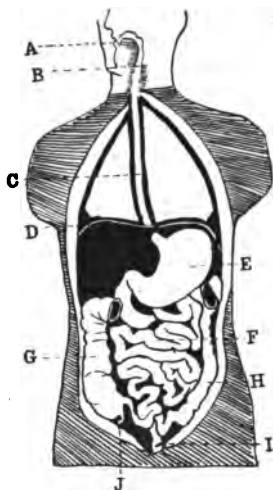
FIG. 48. The digestive tract. A—mouth, B—pharynx, C—esophagus, D—diaphragm, E—stomach, F—small intestine, G and H—colon, I—rectum. Transverse colon is cut out. J—appendix.

These changes break large molecules up into small molecules. For example, the glucose molecule is one-half the size of the cane sugar molecule from which it is derived, and perhaps one-twentieth as large as the starch molecule.

The digestive tract. The long tube of irregular size passing from the mouth through the trunk is known as the digestive tract. Its considerable

length gives large surface for the secretion of digestive juices and for the absorption of food. The greater part of the length, twenty feet or more, is the small intestine, irregularly looped in the middle of the abdomen. The large intestine, the last division of the tract, is about five feet long.

1. Name the part of the digestive tract that connects the mouth with the stomach.

2. The stomach lies in which side of the body?

3. Locate the liver as compared with the stomach.

4. Name in order the parts of the large intestine.

5. Locate the appendix.

6. Locate the pancreas. (See Fig. 52.)

Mouth anatomy. The first digestive change occurs in the mouth. To study the anatomy of the mouth, face a good light and hold a small mirror so that you can get the reflection of the open mouth. The pharynx is a chamber common to the back part of the nose and mouth. Look as far back into the mouth as you can. Hanging down from the roof of the mouth, separating it from the pharynx, is the uvula.

1. Describe the movement of the uvula as you gap.

2. Feel with the tongue; what part of the roof of the mouth is bony? what part is soft?

3. Describe the mucous membrane lining the mouth— its feel, its color, its surface, etc.

Chewing. The chewing of food divides it into small particles so as to expose it more completely

to the action of the digestive fluids. Vegetable foods
need to be chewed more thoroughly than meat
foods because the vegetable cell walls are woody
and cannot be easily digested. Dense vegetable
lumps swallowed without chewing are likely to
remain lumps all the way through the digestive
tract, and the contents of the cells are not digested
out. The connective tissue and cell walls of meat,
on the other hand, are digestible. A piece of meat
in the stomach is reduced to minute fragments, and
the digestive fluids get access to all parts of it.
Most of us do not sufficiently appreciate the value
of thoroughly chewing our food; or we are in too
great a hurry, and chewing is necessarily a slow
process. Those who make a habit of chewing their
food well find that it tastes better, digests more
easily and more thoroughly, and therefore less of
it is needed.

1. Does a lump of food have more or less surface than
the particles to which it is reduced in chewing?

2. Why is chewed food easier to swallow?

3. What animals chew their food much?

4. What animals chew their food little?

5. What kinds of food are used by animals of the first
class?

6. What kinds by animals of the second class?

The teeth. Study your teeth, using a mirror.

1. How many are there in each jaw?

2. According to the appearance of the crowns, divide

the teeth into two classes. What are the differences between the classes (a) in form, (b) in function?

3. Give the number in each class.

4. When the jaws close, how do the back teeth meet?

5. How do the front teeth meet?

6. Explain how the meeting suits the function.

7. The dentist names the teeth on each side of each jaw, beginning in the middle,—central incisor, lateral incisor, cuspid, first bicuspid, second bicuspid, first molar, second molar, third molar.

8. What is the meaning of each of these terms?

9. Describe the crown of each kind.

10. From extracted specimens describe the roots—number and shape—of as many as you can get.

11. Put a tooth into a bottle of dilute hydrochloric acid. The bubbles you see are carbon dioxide, which is produced when hydrochloric acid comes in contact with limestone. We infer that the tooth contains a limestone substance. After the tooth has been in the acid for a day how has it changed? The material not destroyed by the acid is an animal substance much like gristle.

FIG. 49. Section through a tooth. e— enamel, d— dentine, p— pulp cavity, g — gums, b— bone, c — cement.

12. How does the substance of a tooth compare with the substance of a bone?

13. Since the tooth is alive, all parts (except the enamel) must be supplied with food and oxygen.

The dentine is similar to bone in having minute tubes through which the blood and small nerve fibers can penetrate to all parts of it. Where do the blood vessels and nerves lie? (See Fig. 49.)

14. The gums cover what part of the tooth?

Care of the teeth. The enamel of the teeth is the hardest substance in the body. It has neither pores, blood vessels nor nerves, but forms a compact surface to protect the softer parts of the tooth. Since it contains no protoplasm and has no blood supply, it cannot be repaired if it is injured. If it is cracked or worn through, there is exposed the porous, moist dentine in which germs rapidly produce decay. The enamel is sometimes injured by picking the teeth with pins and other hard instruments. A quill or wood pick or a thread is better. There is no better health investment than the care bestowed upon the teeth.

Hot and cold drinks should be kept from the teeth as much as possible, because a sudden change of temperature is likely to crack the enamel. Bits of food allowed to remain between the teeth decay, producing an acid that destroys the enamel. Remove them with a pick or thread after each meal. The teeth should also be brushed at least twice a day. The brush should have bristles of different lengths, that some may go between the teeth. If the brush is moved with a turning motion from the gums to the teeth, the bristles will not catch under the gums, rubbing them back and making them sore. A gritty powder will wear off the enamel, and therefore should be used but seldom; a soft chalk or orris root is sufficient for the daily cleaning. A mild antiseptic mouth wash, worked with

closed lips back and forth between the teeth once a day, is beneficial.

Have your teeth carefully inspected once or twice a year. Have cavities filled as soon as they appear, before they get large. They give the breath a bad odor and harbor swarms of bacteria. The dentist scrapes out all the decay and germs and puts into the clean cavity a filling so tight as to exclude germs, and so decay is stopped. As you observe teeth, note whether you find the cavities and fillings more often at the edges or at the fronts of the teeth. Why is this so?

The saliva. By means of the saliva starch is chemically changed into a form of sugar called maltose. Only a small part of the starch we eat has time to change to maltose under the influence of saliva; the remainder must be digested in the intestine.

1. When the flow of saliva is checked through fear, embarrassment or some other emotion, how does the mouth feel?

2. How is speech affected?

3. How does saliva assist mechanically in swallowing food?

4. How many uses of the saliva can you enumerate?

The secretion of saliva. The saliva is secreted by three pairs of glands. The largest (parotid) lies below and in front of the ear, another (submaxillary) lies near the angle of the jaw, and the third

(sublingual) near the center of the floor of the mouth under the tongue. The duct from the parotid gland opens in a little projection in the cheek. Look for it, using a mirror. Observe near which tooth it is. The other ducts open in a small ridge on each side under the tongue. Look for the ridge, using a mirror. In Figure 50 you can see that the cells of the gland are well supplied with fluid from the blood vessels. The cells take in this fluid on one side, and from it produce saliva, which they exude into the duct on the other side.
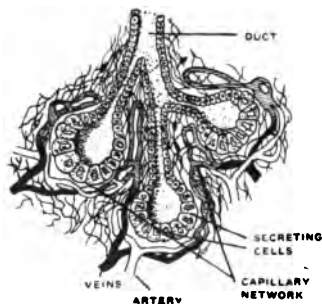
FIG. 50. Diagram of a small portion of a gland, much magnified.

The tongue. Nerves of taste end in the papillae of the tongue, and also in the roof of the mouth. Taste is not an infallible guide in eating; it does not enable us always to distinguish harmful things from wholesome foods. But it does enable us to some extent to choose the good; for when we have once learned the taste of substances we can identify them by tasting. A very important function of taste is to stimulate the secretion of digestive fluids. When things taste good more saliva and gastric juices are secreted, and so digestion is promoted.

1. What does the tongue do when we chew?

2. Examine a small piece of lamb or hog tongue from the meat market; of what kind of tissue is it composed?

3. Looking in a mirror, compare the upper with the under surface of your tongue.

4. There are three kinds of papillae on the tongue. The fungiform are seen as small red spots; the filiform are light colored. Which are more numerous?

5. The circumvallate papillae lie far back on the tongue, are red and large. How many of them can you see?

6. What does the tongue do when you swallow?

Swallowing. When the tongue has pushed the food back into the pharynx (see Figure 37), the muscular walls of the latter contract and squeeze the food into the esophagus. The circular muscles of the esophagus then contract successively, beginning at the top, and so force the food ahead of the contracting rings into the stomach. Observe the process in the throat of a horse while drinking. The

Fig. 51. Diagrammatic cross section of the abdomen, showing the peritoneum lining the wall of the cavity and folding back over the stomach, intestine and liver.

movements of the mouth and the beginning of swallowing are voluntary processes, but most of the swallowing and all the subsequent digestive movements are involuntary. It behooves us, then,

to do well the part of digestion we control. Chew the food thoroughly, especially raw vegetable foods. Do the grinding in the mouth and so lighten the work of the stomach. Taste the food and enjoy the taste. Mix it with saliva to make it swallow easily; never wash a mouthful of food down with gulps of liquid. The practice is bad from a hygienic as well as from an aesthetic point of view.

The peritoneum. The smooth, glistening, moist membrane lining the abdominal cavity is the peritoneum. From the back it folds over the organs of the abdomen, forming their outer or serous coat. The digestive tract is, therefore, suspended by a double fold of peritoneum, which in this location is called the mesentery. Between these folds lie the blood vessels, lymphatics, nerves and fat. The mesentery has the appearance of a single instead of a double membrane. From the lower surface of the stomach the covering membrane loops down in front of the bowels like an apron. It is called the omentum, and it serves for the storage of fat. The mesentery supporting the twenty-five or thirty feet of intestine is attached to the body wall in the upper part of the abdominal cavity, so that the organs hang loosely suspended in the cavity; and from this center of attachment the blood vessels, lymphatics, and nerves radiate. This loose suspension of the bowels and their smooth serous cover-

ing give the loops of the intestine perfect freedom of motion on each other.

The stomach. In Figure 52 the stomach is viewed from the front. The lining of the stomach is a mucous membrane, continuous with that of the esophagus and mouth. It is too large to fit the stomach and is, therefore, thrown into long folds running lengthwise of the organ. This membrane secretes a digestive fluid, the gastric juice. To give more surface for secreting cells, and so increase the secretion, the mucous membrane dips down into the under-lying spongy tissue in many little pockets called gastric glands. (See Figure 54.) Beneath the cells of the mucous membrane are blood vessels, lying in the spongy, fibrous sub-mucous layer. Next comes a

FIG. 52. Stomach and pancreas, with ducts from the liver and pancreas joining as they enter the intestine.

layer composed of bands of muscle running in different directions. Outside of all is the serous covering.

Stomach digestion. The muscles of the stomach have a great deal of work to do in preparing the food for the intestine. While the mass of food is held in the pouch (to the left), a portion is

squeezed off by muscular contraction and worked down to the pyloric end of the stomach, where it is moved slowly back and forth (see Figure 53) till it is well mixed with gastric juice and made very watery; then it is squeezed through the pylorus into the duodenum. The pylorus is kept closed by a ring of muscle which remains constricted while the food is being moved about in the stomach, but opens occasionally when food is suitably prepared to pass on. When the stomach digestion is finished, a strong contraction of the muscles will force through the pylorus the lumps that have resisted the action of the gastric juice.
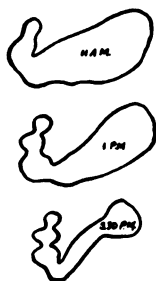
FIG. 53. X-ray of the contents of the stomach, showing the contractions o f the stomach muscles to "churn" and expell the food.

Gastric juice. Like the other digestive fluids, the gastric juice is nearly all (99.4%) water. Dissolved in the water are the digestive substances, the chief of which is pepsin. It is sometimes extracted from the stomachs of freshly slaughtered animals and used in pepsin gum and pepsin tablets. Another substance is rennin, which is obtained from the calf's stomach and used to curdle milk in cheese-making. It has the function of curdling milk in the human stomach. Would you expect it to be more abundant in the stomach of a child or of an

adult? Hydrochloric acid is also present in small amount, and is an indispensable constituent of gastric juice. The pepsin and hydrochloric acid act on nitrogenous foods, dissolving them and bringing them to suitable chemical conditions for assimilation.

If a piece of lean meat is taken into the stomach, the gastric juice comes in contact with its surface, dissolves the cell walls and the protoplasm within the cell, and a considerable amount of the connective tissue between the cells. The lump of meat goes to pieces; but there usually remains undissolved a few shreds of tough connective tissue. Fat meat consists of a network of connective tissue, holding the cells of protoplasm distended with oil. The gastric juice digests the protoplasm and connective tissue, and so frees the oil, which becomes emulsified—scattered in very small drops through the watery fluid.

A piece of vegetable has woody cell walls which the gastric juice cannot dissolve. If swallowed in a lump, it is likely to remain a lump in the stomach and through the intestines. The gastric juice may get through the walls of the cells near the surface of the lump and digest out the nitrogenous materials, but most of the mass will remain undigested. Cooking and chewing disintegrate the mass and break the cell walls, so the contents of the cells can be thoroughly digested.

The time of digestion. The length of time that some common foods remain in the stomach is given in the following table. The food is not, when it passes on into the intestine, fully digested. The fats are emulsified but chemically unchanged, the starches and sugars are very slightly affected by the saliva, and even the nitrogenous foods are only partly digested.

	Hours		Hours
Beef, roasted or broiled...	3	Oysters, raw	3
fried	4	stewed	3½
Mutton, boiled or broiled..	3	Milk, boiled	2
roasted	3¼	raw	2¼
Pork steak, broiled.......	3¼	Beans, in pod, boiled......	2½
roast	5¼	Potatoes, baked	2½
Brains, boiled.............	1¾	boiled	3½
Chicken, boiled or roast...	4	Cabbage, raw	2½
Trout, boiled or fried.....	1½	boiled	4½
Bass, broiled.............	3	Turnips, boiled............	3½
Eggs, raw	2	Rice	1
soft boiled........	3	Bread, corn	3¼
hard boiled or fried	3½	wheat	3½

The foods that remain long in the stomach are, as a rule, difficult to digest. In fact, difficult to digest means little more than taking a long time, together with its logical accompaniments, the use of more gastric juice, more muscular energy, and more chance for fermentation. Foods digested in a short time are preferable, especially for people having difficulty with digestion. Most people who take plenty of outdoor exercise do not need to avoid a food because its time of digestion is long.

There are individual differences in the time of digesting foods. We have to learn, by trying, which kinds of food we can easily digest and which we cannot; and yet people, whimsical about their eating, are more often deranged in their imagination than in their stomachs, and do not really need to refrain from the things they avoid.

Cooking. The purpose of cooking is to make the food more palatable and more digestible, and to kill the germs and parasites. Cooking foods to improve their tastes will not be considered here. Most harmful germs and parasites are killed by the temperature of boiling water, therefore if food is cooked thoroughly it is made sterile. Meat from an animal in sound health is wholesome and most easily digested raw. But occasionally a diseased animal is slaughtered and sold. Thus raw meat sometimes contains live bacteria of disease. Some diseased pork contains tiny worms (trichina) in a resting stage. When taken into the stomach alive, they become active and produce thousands of young, which spread through the body, settling in the muscles and producing a very painful and sometimes fatal illness. The tapeworm is another parasite imbedded, in a resting stage, in eertain diseased beef and pork. If this meat is eaten raw the parasite may lodge and grow in the human intestine. It rarely produces serious results, and is removed without difficulty.

The bacteria of decay, whose growth in meat makes it tainted, produce poisons called ptomaines. Cooking the meat kills the bacteria, but does not render harmless the ptomaines. Tainted meat, spoiled ice creams, and other substances containing ptomaines can in no way be made fit for eating.

One effect of boiling vegetables and dry grains is to make them soft, so that they can be chewed fine. The time required differs for different foods. When the food is soft it is sufficiently cooked. Boiling also causes the starch grains to absorb water, to swell and become permeable to the digestive juices. Cooked starch is much more digestible than raw starch. In flour and meal the starch is more accessible to the water because it is either broken out of the cells, or the cells are only a few in a small lump, so a shorter time of boiling is required. Moist vegetables like potatoes may be either boiled or baked; there is enough water in them. Dry things like rice or oatmeal must be boiled or steamed, and the water on them should be enough to make the grain soft, else they are not perfectly cooked. Sugary fruits and vegetables are cooked chiefly to make the woody parts soft. The less cooking lean meat has the more easily it is digested, but the tough parts of meat, the connective tissues, are made soft only by being subjected to moist heat for two or three hours or more. Four or five hours is not too much for soup meat. Eggs are

more easily digested raw. If they are cooked at a temperature a few degrees below the boiling point they will be more easily digested than if boiled. Omelet is easily digested, fried eggs are not.

Pasteurization. Raw milk tastes better than boiled milk and it is more easily digested by children. Boiled milk often causes constipation. But the danger from raw milk is that it usually contains an enormous number of bacteria. It has been found that heating to a degree considerably below the boiling point kills practically all harmful germs and does not have the objectionable effects that boiling has. This heating is called *Pasteurization*. The best method is to heat the milk at the bottling factory, to a temperature of 140 or 160 degrees, for about half an hour, then cool quickly, put in sterilized glass bottles and keep cool until used. Pasteurization can easily be done in the home by the following procedure: Place the bottle of milk in a pail, on a saucer or something to hold it off the bottom; pour warm water around it to within two inches of the top (keep the stopper on all the time); bring the water to a boil (of course the milk is not boiling); immediately remove the bottle; cool it and keep it cool.

Raw milk is very likely to give bottle-fed babies an intestinal infection which is frequently fatal. This is largely avoided by Pasteurization. Even boiled milk is better than raw milk for sick babies.

Alcohol. There is very little absorption of water or of digested food in the stomach. But certain fluids, among them alcohol, are largely absorbed in the stomach. They pass directly through the mucous membrane and enter the capillaries, from which they quickly pass into the general circulation. Thus the effect of alcohol can be noticed within a few minutes after a drink is taken. Some people are in the habit of drinking a glass of wine with their dinner, to hasten the digestion of the food. Authorities are not altogether agreed as to the effect of a small quantity of alcohol thus taken; they rather generally concur in the opinion that the habitual use of alcohol with meals is unhygienic. A large quantity of alcohol, especially of strong spirits, is exceedingly harmful to the mucous membrane. It produces congestion and abnormal secretion of mucus (catarrh), which interferes with digestion. In old topers the mucous membrane is often covered with ulcers, and is usually so thoroughly deranged that it is unable to fulfill its function. There is almost no stomach digestion in such cases.

Tobacco. Tobacco produces vomiting; it is an emetic, as many boys know. The stomachs of those accustomed to its use have become so dulled by its influence that they do not reject the poison when taken in the ordinary small quantity. The impaired sensitiveness of the mucous membrane

extends to other things besides tobacco. Students in a dissecting room, workers in fertilizer factories and tanneries, find the stenches less intolerable when they use tobacco. The mild food stimuli, so important to digestion, have little effect on a stomach dulled by tobacco.

Intestinal digestion. The food, mixed with gastric juice, passing from the stomach to the small intestine is called chyme. It is composed of very fine particles, partly digested and mixed with so

LONGITUDINAL   CIRCULAR

LONGITUDINAL SECTION OF THE SMALL INTESTINE

GLANDS   VILLI

SUBMUCOUS   MUCOUS
MUSCULAR   COAT   COAT
COAT
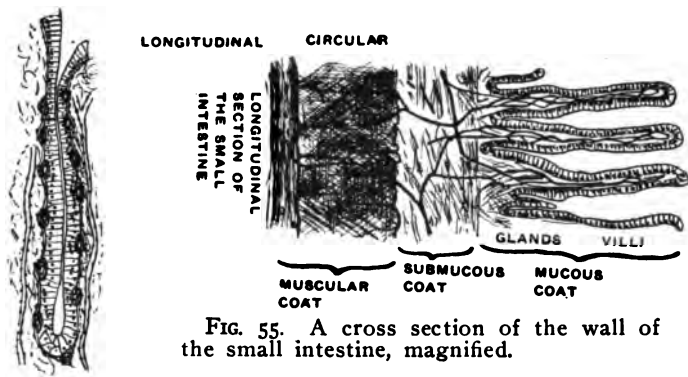
FIG. 55. A cross section of the wall of the small intestine, magnified.

FIG. 54. A longitudinal and a cross section of a gland which produces gastric juice, much magnified.

much fluid that it has a thin consistency and moves along the intestine easily. The intestinal walls are like those of the stomach in that they have a mucous lining containing secreting glands (Figure 54), a submucous layer, a muscular layer of circular and another of longitudinal fibers, and a serous covering (Figure 55). The mucous layer is

longer than the other layers, and is therefore
thrown into folds across the tube. These folds par-
tially disappear when the intestine is distended. The
surface of the mucous membrane is further in-
creased by the villi, minute projections like the fin-
gers of a glove, which project into the intestinal
cavity. (See Figures 55 and 56.) As the acid
chyme comes into the intestine, its presence stim-
ulates the mucous membrane to secrete a fluid
called intestinal juice. From the gall bladder and
liver a stream of bile comes to join the chyme, and
from the pancreas comes the pancreatic juice, the
most important of all the digestive juices. These
fluids are all alkaline.

The intestinal juice is very similar to saliva in
its digestive action, changing starch into maltose.
It also changes maltose and common sugar into a
simpler kind of sugar, glucose or grape sugar.
This is ready for the protoplasm and is found all
through the body. The bile assists in the digestion
of fat. The pancreatic juice acts on all kinds of
food. It contains at least three digestive ferments,
one to act on sugars and starches, one for the
nitrogenous foods, and one for fats.

The food in the intestine is "worked," squeezed
back and forth and mixed with the digestive fluids,
by the action of the muscles in the wall of the
intestine. At intervals a peristaltic. wave passes
along a section of the intestine, sending the food

along several inches. This wave is in appearance like the crawling movement of an earthworm. It is caused by the contraction of one portion after another of the muscular walls. The food is again worked by muscular contraction and again sent forward by another peristalsis, and so on. The chemical changes of digestion are proceeding all this time, and some of the digested food is being absorbed. It usually requires several hours, eight or ten, for a stomachful of food to pass through the small intestine.

There is a flap of mucous membrane at the opening from the small intestine into the large, which makes difficult a return movement of the contents of the large intestine. The small intestine is about as large as the thumb, while the diameter of the large intestine is about twice as great. The colon has frequent constrictions, which partially divide it up into little bays. The structure of the walls is practically the same as that of the small intestine, but there are no villi. The glands secrete, instead of a digestive juice, a slimy mucus which makes the contents of the tube move more easily. The food enters the large intestine thin and watery. As it is forced along by occasional muscular contractions, the digestive process is concluded and the liquid absorbed, leaving the contents of the lower colon and rectum thick and firm. Although the large intestine is only about five feet long, the

food takes as much time to pass through it as through the twenty feet of small intestine. After the liquid has been absorbed from the intestine, there remains in the tube the woody parts of the vegetables we eat, hard, resisting bits of meat, and brown-colored waste from the bile. This material is called the feces.

1. Why has the large intestine a greater diameter than the small?

2. Why are the walls of the colon wrinkled in deep folds?

Intestinal hygiene. It is of the utmost importance that the colon should not become clogged with fecal matter. It should be emptied at a regular time every day. If a generous amount of food is eaten, some of it usually escapes digestion and so remains unabsorbed in the colon. The conditions necessary for the growth of bacteria are here present,—warmth, moisture and food. The gastric juice is acid and kills most of the bacteria which are taken into the stomach; but all the juices of the intestine are alkaline and therefore provide a medium favorable to the growth of germs. There are always some bacteria present in the intestine, often producing as they grow offensive gases and sometimes poisons. If the bowels go unemptied two or three days, the quantity of poisons produced and absorbed is so great as to cause a dull feeling, often headache, sometimes a high fever.

This is called auto-intoxication, and may become a serious matter if the neglect is prolonged. Do not go to advertised medicines for relief, but consult a reliable physician. Massage of the abdomen may stimulate the movement of sluggish bowels. Proper exercise and suitable diet will do a great deal toward keeping the bowels active and in good condition. Fruits, large amounts of water, and vegetable foods with much woody substance are especially recommended to people who suffer from constipation.

Drugs. Since alcohol is so largely absorbed in the stomach, it comes to the intestine in a very dilute form, and does not have such a ruinous effect on the mucous membrane. It often produces an increased secretion of the digestive juices, but these secretions are not normal and do not have perfect digestive function. Though brandy is used as a cure for diarrhea, persons addicted to the excessive use of liquors usually suffer from a severe diarrhea. How does the blood circulation of the liver make that organ especially exposed to the attacks of alcohol? Two forms of change in the liver tissue are common, and both seriously impair its work. First, the protoplasm in the secreting liver cells may be partly replaced by fat; and second, the cells may completely disappear and be replaced by scar tissue (cirrhosis). Opium diminishes the secretion of all the digestive juices, and

so weakens the muscular activity of the digestive tract as to result in serious constipation.

Absorption of food. The absorbing surface of the small intestine is much increased by the villi. These are about 1/25 of an inch in length and are thickly distributed over the surface. In absorption
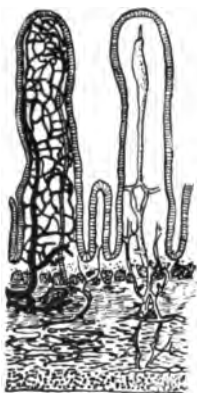
FIG. 56. Diagram showing two villi, the one at the right with the capillaries removed to show clearly the lacteals. A lacteal network and blood vessels are in the submucous coat also.

the food must first go through the cells which cover the villus and make the compact lining of the intestine. The food enters the cells not simply by soaking in, but the cell walls are so thin and permeable that the protoplasm is practically in contact with the food and by its own activity helps take it in, in much the same way as white blood corpuscles take in bacteria. When the food enters the cells of the mucous membrane, not all parts of it are in the chemical forms required for assimilation. Some of it is changed during its passage through the cells of the membrane, some is changed in the liver, and some perhaps in the lymph glands and in other places in the body. From the cells the food is passed into the interior of the villus, where most of the watery part, the nitrogenous substances and sugar, is taken into the capil-

laries, passing thence through small veins to the
portal vein, which distributes it to the liver. From
the capillaries of the liver the hepatic veins collect
the blood, containing fresh food, and carry it to the
ascending vena cava, which conducts it to the
heart. The oily part of the food does not easily get
into the capillaries, but it is readily taken up by
the lymphatics, here called lacteals. Small muscles
in the villi occasionally contract and squeeze the
fluid contained in the small lacteals into larger
tubes which convey it to the thoracic duct (cisterna
chyli), through which it is carried to a vein in the
neck and with the blood goes on to the heart.

The lacteals get their name from the milk-col-
ored fluid, chyle, which they carry.

1. Put a few drops of some nearly colorless oil (olive
or sperm) into a bottle half full of water and shake it
vigorously, making an emulsion. How does it change
by standing a few minutes?

2. Add a little bile or mucilage and shake again. Is the
emulsion more or less transient than at first?

3. Why does chyle look white?

4. Trace the route along which each of the following
foods goes, after it is digested, to get to the heart: sugar,
lean meat, butter, starch, cheese, potato, fat meat.

Fats. The necessity for any chemical change in
fats may not at first be apparent. It is already a
fluid in the stomach, and it is in a suitable chemical
condition to circulate in the blood and be
assimilated. The problem is to get the fat through

the watery mucous membrane. Soap is commonly made by boiling fats or oils in alkalies. The digestive juices in the intestine are alkaline. At least part of the fat is, in the intestine, changed to soap, which readily dissolves and is absorbed through the watery membrane. Some of the fat is split into fatty acids and glycerine, both of which are easily absorbed. The soap, fatty acids and glycerine are, to some extent, perhaps completely, recombined in the cells of the mucous membrane into fat. The tiny drops of fat can, under the microscope, be seen in and behind the cells. They pass on into the lacteals. Some of the fat, also, is generally supposed to be absorbed as oil, through the activity of the protoplasm of the cells covering the villus, and probably under the influence of a coating of bile and pancreatic juice.

Resumé

1. Which class of foods do civilized people use most?

2. In the digestive process, starch is changed into what?

3. Name the fluids that work this change, and state where each is produced.

4. By what fluids is sugar digested?

5. Nitrogenous foods are digested by what fluids?

6. Where is each of these fluids produced?

7. Name the juices involved in the digestion of each of the following foods: bread and butter, eggs, roast pork, oatmeal with sugar and cream, mince pie, beef steak, pork and beans.

Function of the liver. The bile is a very com-
plex fluid. It assists in the digestion of fat. It is
in part nitrogenous material that can be used again
in the chemical activities of the cell, and in part
substances probably altogether useless to the body.
As the bile passes along the intestine there is oppor-
tunity for the useful part to be absorbed and enter
the blood again. The useless substances are mostly
in small brown or yellow grains, and though some
are absorbed the remainder are discharged with
the undigested fragments of food. Besides the
work of excreting bile, the liver has other very
important work to do. When the blood from the
portal vein, containing much sugar just absorbed,
comes into the capillaries of the liver, the liver
cells take out a large part of the sugar and turn it
into glycogen, almost like starch, which they store
up in themselves. Then when the sugar in the
blood is used up by the protoplasm of the body and
there is no supply coming from the intestines, the
glycogen is gradually turned back to sugar and is
taken up and carried through the body by the
blood. This is a very simple process, since the
difference between glycogen ($C_6H_{10}O_5$) and sugar
($C_6H_{12}O_6$) is slight. Consider what must be taken
from the sugar to change it into glycogen. Gly-
cogen is produced from nitrogenous foods also,
when there is more nitrogenous food in the blood
than is needed to replace the proteid waste. In

this action there results a nitrogenous residue
called urea. Also, the nitrogenous waste produced
in the breaking down of protoplasm comes to the
liver in the general blood circulation, and is there
split into glycogen and urea. The latter is of no
further use in the body and is removed by the
kidneys.

CHAPTER XI

THE SKIN

Imagine the body without a skin, the moist muscle and connective tissue exposed to the air. The lymph would ooze out and dry and the cells of the tissues that lie at the surface would die.

How would the surface thus exposed be affected by the clothing and by other objects that touch it? State another need of skin.

We can handle arsenic and many other chemical poisons without being injured. How would it be if we had no skin? State another need of skin.

How would the body be affected by the bacteria that touch it if we had no skin? What further use, then, have we for a skin?

Besides serving these ends, the skin is the chief means of regulating the temperature of the body and it contains the organs at the ends of the nerves by which we have the sense of touch and of temperature. We must now see how the structure of the skin fits it for these uses.

Epidermis. Study Figure 57.

1. What two general parts or layers has the skin?
2. Of what is the outer part composed? The inner

layer is chiefly composed of fibers, which serve as a support for the blood vessels, nerves, glands, fat, etc.

3. Are any blood vessels shown in the epidermis?

4. How can the epidermis be provided with the conditions necessary to life if it has no blood vessels?

5. If the oxygen and food had to come to these cells from the dermis, which cells would get the larger supply?

6. What would be the fate of cells removed several tiers from the source of supply?
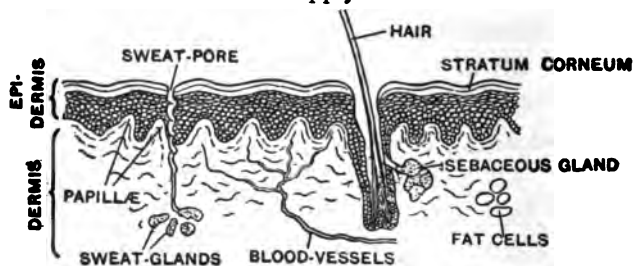
FIG. 57. A section of the skin, highly magnified. The stratum corneum is the scaly surface continually wearing off. The papillæ contain the nerves of touch.

As might be expected, the growing cells are at the bottom of the epidermis. As they increase in number, some cells are crowded away from the source of supply and become thinner and dryer till, at the surface, they become hard scales. The old scales are constantly being worn and washed off as the new form under them. The protoplasm of the outer cells, before it dies, produces a waxy substance that renders the cells hard and nearly impervious to water and germs.

Dermis. Examine with a magnifying glass the torn edge of a piece of leather. The threads seen

are the fibers of the dermis.   In the preparation of
most leathers the epidermis is rubbed off and the
inner part of the dermis scraped and shaved away,
leaving little more than the compact fibers of the
·skin.   A tanner says the skin is stronger than the
leather made from it.   Beneath the skin, or, per-
haps more exactly, forming the deeper part of it,
is a loose fibrous tissue (subcutaneous) which con-
nects it with the underlying tissues.   In the deeper
part of the dermis and in the subcutaneous tissue
are groups of fat cells.   They serve as a pad and
help protect the body from blows.   They also
make the skin smooth and plump.

1. Does a girl usually have more or less fat under the
skin than a boy?.

2. In old people the fat is largely absorbed from be-
neath the skin; what appearance does this give to the
skin?

3. Which part of the skin serves as a water tight cover-
ing to keep the moisture of the body from oozing away
or evaporating?

4. Which part of the skin provides the mechanical
strength for protecting the underlying tissue from blows
and tears?

5. Which part thickens where there is much chafing
and wear, as in the palms of the hands and the soles of
the feet?

6. Stick a pin slanting into the callus.   How do you
know which part is here thicker?

7. Which part of the skin protects us against chemical
and bacterial poisons?

8. Thousands of bacteria get lodged on the skin every day; what becomes of them as the epidermal scales fall off?

The sweat glands. The minute tubes opening at the surface of the skin are called sweat glands. The tube in diameter is 1/60 to 1/80 of an inch. Though it reaches only to the bottom of the dermis, its length is much greater than the thickness of the skin.

The cells are epidermal in their origin, though they extend into the dermis. They take the fluid from the blood and from it produce the perspiration with which they fill the tube. The perspiration is more than 99% water, dissolved in which are some salts and waste matter. Its chief function is the regulation of the temperature of the body, but it is also an excretion.

1. By what form does the tube of the sweat gland get considerable length without extending very deep?

2. Does this form make it easier or more difficult to supply the cells composing the wall of the tube with fluid from the blood vessels.

3. Examine the tip of the finger with a magnifying glass. Are the pores, the openings of the sweat glands, located along the ridges, or in the grooves?

4. Pinch and rub the finger, clasp it in the other hand, or hold it in hot water for a minute and then dry quickly, to see if you can make the perspiration appear at the pores.

If you can get droplets of perspiration on the back of the hand or fingers, describe the arrangement of the pores.

Touch the palmar surface of the last joint of each finger to an ink-pad and then to the page of your note book. Better than an ink-pad is a piece of glass on which printers' or engravers' ink has been thinly spread with a pad or roller. Wash the ink off your finger with a rag soaked in gasoline.

5. Is the arrangement of ridges exactly the same on all the fingers?

6. Are any two finger prints altogether alike?

7. In what particulars are they all similar?

8. Describe the surface of the back of the finger seen under a lens.

The hair. Like the sweat glands, the hair is epidermal in structure; it grows from cells at the bottom of a follicle which dips down into the dermis, but is lined with epidermal cells. The bulb from which the hair grows contains blood vessels and nerves and is dermal, but is covered

FIG. 58. A surface view of a portion of a hair, B—longitudinal section of the same, highly magnified.

with epidermal cells. A tiny muscle is fastened to the root of the hair and, in the common animals, is able by its contraction to stand the hair up straight. The hair is a slender tube of hard dry cells packed and cemented together, the central part being filled with softer and more moist cells containing coloring matter. Of course, the hair grows only at the lower end, where it receives

accretions from the live cells. The human hair is chiefly an ornament, though its protective function, especially on the head, is considerable. The well-being of the hair depends on the healthfulness of the scalp. Both hair and scalp should be washed regularly and the hair brushed vigorously but not harshly each day. Brushing and combing the hair brings the oil out to the ends of the hairs, rendering them less likely to become brittle and break. Animals shed their hair with the change of season, but human hairs drop out irregularly, a few at a time. If the bulb at the root of the hair is healthy, a new hair is produced, starting even before the old has dropped out. Often a poor growth of hair can be improved by treatment of the skin that produces it. A reputable physician should be consulted. There is no magic lotion or oil that will make hair grow.

The nails. Like the hair, the nails of the fingers and toes are hardened epidermal cells. The light area at the base, with a curved border, is called lunula (little moon). The nail grows by accretions from the epidermal cells of the lunula and from those touching the covered root of the nail. Press on the pink part of the nail to see if it seems thicker in one place than another. The nails are useful in protecting the finger tips and in picking up small things. They stiffen the ends of the toes and so help in walking. They should be trimmed smooth,

about even with the flesh tip of the finger; and the skin at the back of the nail should be rubbed gently back if it is stretched out by adhesion to the grow-ing nail. The nails trim best when softened by warm water.

Baths. There are two distinct purposes in bath-ing. The warm bath is for the purpose of cleansing the skin. It should be taken just before going to bed, since it leaves the skin relaxed, the blood ves-sels dilated and in no condition to endure drafts and changes of temperature. The cold bath is a stimulus. It should be taken on rising in the morn-ing. The proper temperature of the water depends on the vigor of the bather; a man of rare vigor can stand it ice cold, but common hydrant water is severe enough for most persons. The cold bath should last for a minute or two, or even less, and should be followed by a brisk rub. The cold bath is a severe stimulus, beneficial to those who react well from it, but not advisable for others. Many people, in fact, are greatly injured by subjecting themselves to a treatment they cannot endure. A good plan is to begin with water slightly warm and change it gradually to as low a temperature as is bearable, then rub quickly until dry. For those who find the cold bath too severe, a sponge or dry rub may be beneficial.

Temperature. The skin has a very important function in the regulation of the temperature of

the body. Heat is produced by the activities of all the organs, but chiefly by the muscles. The necessary activities of the body in work or play usually produce too much heat, so the temperature is brought to the proper degree by a cooling process. The regulation of the temperature consists chiefly in adjusting the rate of cooling to the rate at which superfluous heat is produced. In the cold, if our muscular activity is slight our temperature may go down, and the body has to bestir itself just to produce heat; that is, we shiver. Generally, however, the regulative action is a process of cooling.

The skin is cooled by imparting its heat to its surroundings through radiation and conduction, and by the evaporation of perspiration. The skin radiates and conducts its heat off much faster when it is very warm than when it is cool. If the body is too warm, the blood supply to the skin is increased, through the action of the vaso-motor nerves on the muscles in the walls of the vessels, the skin becomes very warm and gives off much heat. Some winter day when your fingers are cold and your body is aglow with exercise, hold your hand near your face and feel the radiating heat. If the body is losing too much heat, the blood vessels of the skin are made to contract, less blood can get to the surface, the skin becomes cooler and gives off less heat.

The temperature of the skin is lowered also

through the evaporation of perspiration. Some perspiration is being produced nearly all the time. If the body is not too warm the amount of perspiration is small and may dry as fast as it comes to the surface. If the body is too warm the sweat glands receive a nerve stimulus that makes them work faster, and the body is covered with perspiration, the evaporation of which lowers the temperature.

1. Put a drop of water on your hand, and near it a drop of ether, alcohol, chloroform or gasoline. Which evaporates more rapidly? Which feels cooler? Why?

2. The mere presence of moisture on the skin would not cool it. Heat is used up in evaporating moisture. Does water evaporate more rapidly into a moist or into a dry air?

3. Why does 85 degrees on a sultry day feel warmer than even 95 degrees on a dry day?

Clothing keeps the body warm by shutting off the currents of air which carry away the heat from the body, and also by checking the radiation from the skin. For very cold climates the outer clothing should be of compact weave or of skins, to keep out the wind. Sudden changes in the temperature of the skin are harmful, therefore poor conductors of heat are better than good conductors. For this reason silk and wool are more desirable than cotton or linen. In torrid deserts people wear heavy clothing to keep off the heated atmosphere,

sometimes 100 to 110 degrees in the shade, and as a protection from the sun's rays, which have a very high temperature. In moist, torrid regions people wear a minimum amount of clothing. (They live largely in forest shade.) Explain fully the reason for the difference.

Alcohol rubbed on the skin evaporates quickly and thus lowers the temperature of the skin rapidly. This has a tonic effect. Athletes often rub down with alcohol and it is also employed to reduce the temperature in fever. Taken internally, alcohol causes the blood vessels of the skin to relax and become filled with blood. There is thus greater radiation and perspiration. Thus the body is cooled by alcohol. Polar explorers do not drink alcoholic liquors, and people addicted to its use have little power to resist cold. The temperature of an intoxicated man exposed to the cold has been known to be as low as 75 degrees, but this is unusual.

THE KIDNEYS AND THE DUCTLESS GLANDS

The kidneys. The function of the kidneys is to remove from the blood substances that are not needed by the body. The chief of these is the nitrogenous waste. (See Figures 35 and 59.) Notice the location of the kidneys in the body. Each is about five inches long. The secreting cells of the kidneys are arranged in tubes which lie in characteristic loops and coils. Around them are the blood capillaries. The secreting cells take in on one side, the lymph, and on the other side pour into the tube which they surround large quantities of water, holding in solution the various excretions of the kidney. The process of removing these substances is, in part, a simple mechanical filtration, the blood pressure forcing some of the fluid through the cells; and it is, in part, accomplished by the action of the protoplasm in selecting certain substances from the lymph and leaving others. The kidneys do not produce urea, they merely take it out of the blood. The kidneys excrete, besides urea, some carbon dioxide, a variety of salts, and other substances, some of which are poison. The

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secreting tubes empty their secretion, urine, into a receptacle at the inner side of the kidney, from which the ureters convey it to the bladder. This is a muscular sack situated in the anterior part of the pelvis. It is lined with cells several layers deep, so that the contents of the sack may be little ab-sorbed. A single tube (urethra) carries off the urine from the bladder. A circular muscle at the outlet of the bladder, which can be voluntarily relaxed, closes the tube and so retains the urine within the bladder.

The work of the kidneys is indispensable to the body. Like other organs of excretion, the lungs and skin, the kidneys do not need to work to their full capacity to carry off the wastes of the body. They can suffer considerable injury, and still do their necessary work. But if their power to work is lowered to the extent that they are unable to remove the poisonous wastes from the body, severe illness ensues, and unless the defect is remedied death is inevitable.

Alcohol. One of the most pernicious effects of alcoholic liquor is the injury it does to the kidneys. In moderate drinkers, kidney disease is very com-mon. Some of the secreting cells are destroyed, and this compels those that remain to do overwork. Alcohol more than any other factor produces Bright's disease, which usually terminates fatally. Excessive drinkers nearly always have kidney dis-

ease. The light liquors, such as beer, in addition to the effect of the alcohol contained in them, injure the kidneys by the excessive quantity of water which is taken in the large drinks and which must be eliminated by these organs. They are overworked and wear out early.

Internal secretions. The body has several glands without ducts or other outlets for their secretions. The fluids they produce must, therefore, be turned back into the lymph and blood. One of these lies just above the kidney, and so takes the name suprarenal or adrenal gland. (See Figure 59.) The substance
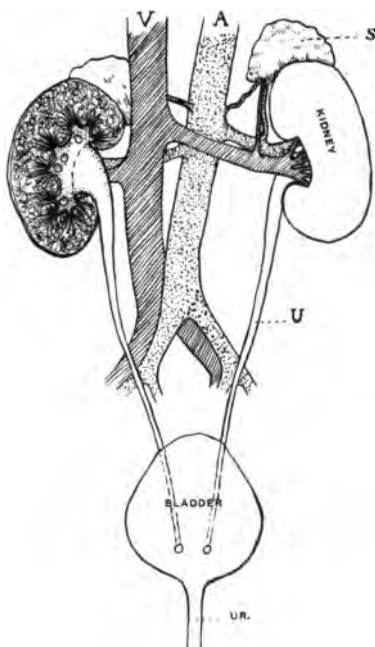
Fig. 59. Diagram of the urinary system. U—ureter, Ur—urethra, A—artery, V—vein, S—suprarenal gland.

it secretes is a stimulus to the vaso-motor nerves, and is needed to keep them in proper tone. Adrenalin is extracted from this gland in sheep and is used in medicine to check hemorrhage and relieve congestion.

Another such gland is the thyroid, which lies ventral to the upper part of the trachea. If the secretions of this gland are deficient, the cells of the body seem to lack their normal function of assimilation and oxidation and neither body nor mind develops fully. If the gland is enlarged (goiter) and produces too much secretion, the activities of the cells may be too great and rapid pulse, headache, and even insanity may result. Upon the first symptoms of enlargement of these glands a good physician should be consulted.

The pancreas, in addition to its work of secreting a digestive juice, produces from special cells an internal secretion. This secretion seems to have a very important function in the regulation of the sugar supply in the blood. The liver (p. 185) and muscles convert sugar into glycogen and store it until it is needed, when they change it back to sugar and send it on in the blood. The normal amount of sugar in the blood is 2%. If the glycogen function is disturbed, or if the sugar is not properly built into fat or oxidized in the cell, the blood becomes overloaded. Then sugar is removed from the blood by the kidneys, and diabetes, or sugar in the urine, is the result. This disease is supposed, in at least a large number of cases, to result from failure of the pancreas to do its proper work. By careful treatment the trouble is often alleviated.

The spleen. The reddish brown oblong organ, lying at the left of the stomach, is the spleen. It has no duct; if there is any secretion, it must be internal. The spleen is sometimes known as the largest lymph node. It is closely related to the lymph system, suffers when the lymphatics are diseased and produces white blood corpuscles, as do the lymph nodes. It is said to disintegrate the red blood corpuscles that have died. It is much swollen and sometimes permanently injured by malaria and typhoid.

THE SPECIAL SENSES

We commonly speak of the "five senses" because there were thought to be just five. We should add to these the muscular sense, the sense of heat, of cold, of pain, and possibly some others.

The function of the organs of special sense is to receive impressions from the world outside the body and convert these impressions into nerve currents. In the lowest groups of animals there are no sense organs and no special senses. All the protoplasm has the nervous function of irritability and responds to such influences as light, warmth and touch. Animals higher in the scale of development, which have well-developed nervous systems, have also special organs to respond to the various outside influences,—ears to receive sound vibrations, to convert them into nerve currents and send them on to the brain; eyes whose sensitive part undergoes a chemical change when exposed to the light and so starts a current to the nerve centers; touch organs whose compression generates nerve currents; organs of smell, of taste, and so on. When the sense organ translates the impressions from the outside world into nerve cur-

rents, the currents come to the brain. We have sensation only with brain action.

The highest classes of animals have these special senses in greatest number and most highly developed. Yet not even man has sense organs to respond to all the forces of the world. We know electricity, magnetism, certain chemical rays from the sun, the X-ray, etc., not directly through sense organs, but by studying their effect on things we can sense. No one knows how many such things there are in the world, things we can never hope to gain direct knowledge of, because our sense organs are so limited. We have no reason to think that any of the lower animals have senses we lack, though some of them have certain senses more acutely developed. The dog can smell things not noticed by us; the eagle's eye is more powerful than ours; it is thought that some insects hear vibrations that are beyond the range of our ears.

A. The Eye

The eye. In the eye we find the same general principles of construction as in the camera. As you learn the parts of the eye, point out the corresponding parts of the camera. (See Figures 60 and 61.) The outer coat of the eyeball is the sclerotic. This coat is tough and strong; it serves as the framework and support for the active parts

of the organ. The part of it we see in each other's
eyes is the white of the eye.

1. Look from the side at the cornea of your neighbor's
eye. Does it curve out more or less than the eyeball?

2. Is it all transparent?

3. Why should it be named cornea (horn)?

4. The part of the eye that gives it color—blue, brown,
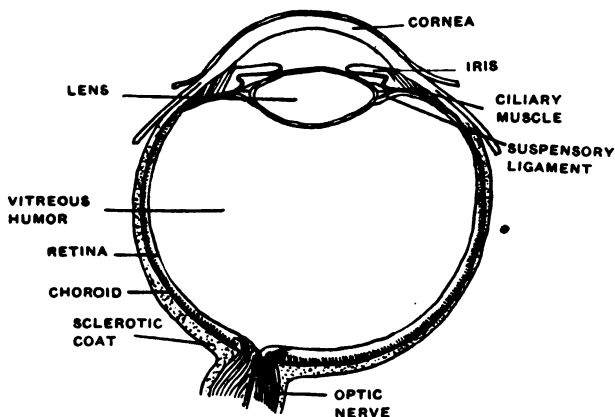
FIG. 60. Section of the eye.

gray, etc.—is the iris. Describe its colors in detail in
your own or in your neighbor's eye.

5. How large is the hole (pupil) in the center of the
iris?

6. Why should it appear black?

7. Have your neighbor face a bright light; shade his
eyes with your hand. While watching his pupil sud-
denly remove your hand and let the bright light shine in
his eyes. What change occurs in the pupils?

The eye chamber is made dark by the choroid
coat, a membrane filled with black granules, lying

just inside the sclerotic coat. The aqueous humor, filling the space between the lens and the cornea, is a thin watery fluid. The vitreous humor is stiff like a soft jelly. The nerves enter the eye in the rear, pass through all three coats and spread out in the retina. The retina is a complex membrane composed of several layers, the outermost of which contains substances that decompose when exposed to light and in so doing generate nerve impulses. The ends of the nerves are most numerous in the
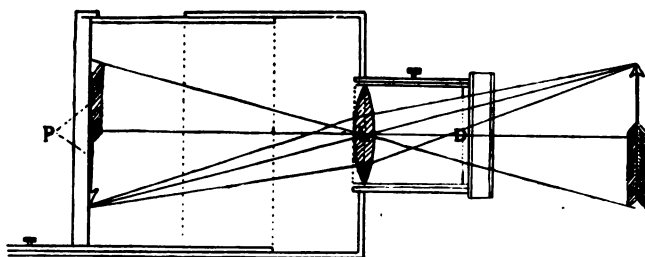
FIG. 61.   Diagram of the camera.   D—diaphragm, P—plate, L—lens.

back part of the chamber where the rays strike from directly in front, and so the eye is most sensitive there. Rays from an object at one side, which enter the eye slanting and strike upon the retina at one side of the chamber, produce but an indistinct image. Therefore, when we wish to give our attention to an object we turn our eyes directly toward it.

The working of the eye. The manner in which the rays of light bend in going from the air into

the denser transparent substances determines the working of the eye. Rays at right angles to a surface do not bend at all. Rays entering obliquely a flat surface, as water or window glass, all bend the same amount, and so keep their former relation to each other. But rays entering a convex surface are brought toward each other, to meet at a point called the focus. (See Figure 62.) In the eye the cornea and the lens have the convex surfaces for focusing the light. From every point of the object
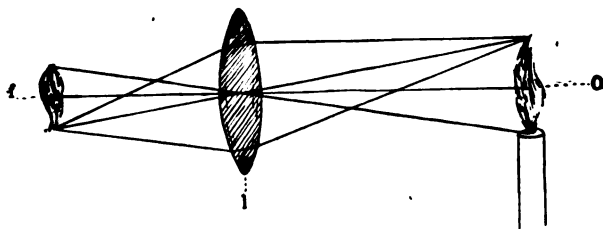
FIG. 62. Rays of light through a lens. O—object, l—lens, f—image at the focus.

seen, rays enter the eye and are brought to a focus on the retina. The very complicated nerve endings in the retina send currents to the brain whenever they are stimulated by light. If the rays are not brought to a perfect focus on the retina, those from one point overlap those from another, and the image is blurred and indistinct. This happens when the curvature of the cornea and lens is not adapted to the length of the eye. Rays nearly parallel are brought to a focus nearer the lens than rays much diverging.

1. Draw a diagram of the lens, and several rays to it from two points, one near and one farther away. From which point do the rays diverge more?

2. If the distance from the lens to the retina is long, can near objects or far objects be seen better? When the eye is too long for the curvature of the lens and cornea the defect is short-sightedness. Objects can then be seen distinctly only when they are very close.

.3. If the distance from the lens to the retina is short, can objects near or far be better seen? If the eye is too short, the defect is long sight, inability to see things clearly that are very near.

4. Does a grandmother hold a needle close or at arm's length to thread it?

5. Is long sight common in young or in old people?

Focusing. How is the focus in a camera adjusted for objects of different distances? Since the length of the eye is unchangeable, the focusing must be done in a different way. The more convex a lens is the more it bends the rays of light. The lens of the eye is changeable. It is fastened around the margin by fibers running to the stiff wall of the eye. These elastic fibers are stretched, and therefore exert a constant pull on the lens, tending to make it thinner. A ring of ciliary muscles (Figure 60) is fastened to the fibers so that when the muscles contract the fibers are drawn toward the lens, the tension is relieved, and the lens becomes more convex. The normal eye can adjust the focus from about eight inches to an unlimited distance. It is

best for the eyes to have the book fifteen to eighteen inches away, and to look off occasionally.

1. Would these muscles contract to adjust the focus to a near or to a far object?

2. If your eyes are tired of reading why does it rest them to look at some object in the street?

3. How near to your face can you hold a book and read it easily?

The use of spectacles. Spectacles are used to compensate for several defects of the eyes. If the eye is short-sighted the rays that enter it must diverge much, as from a near object, if they are to focus on the retina. Therefore concave glasses are used, which cause rays from a distant object to diverge as much as they would from a near object. If the eye is long-sighted, the glasses are convex so as to make the rays less diverging, as though they came from a greater distance.

One of the most common defects corrected by glasses is astigmatism. This is an irregularity in the curve of the eye, a curve like the side of an egg instead of the surface of a sphere, which results in only part of the rays focusing on the retina at once. Part of an object therefore appears clear while part is dim.

External mechanism. The eye is turned in its socket by six muscles, fastened at one end to the eyeball and at the other end to the back part of the bony socket of the eye. The muscle at the

right side of the eye contracts to turn the eye to
the right, the muscle on the under side contracts
to turn the eye down, and so on. By muscles run-
ning obliquely, the eye can be rotated. If the inside
muscle (the side toward the nose) is too short, it
turns the eye inward so that it does not look
straight forward when the other eye does; its line
of sight crosses that of the straight eye. "Cross-
eye" can often be corrected if·treated carefully in
childhood. The "wall eye" looks outward when the
other is directed forward. The external muscles
are too short.

The moisture drains from the eye through a tiny
tube emptying into the nose cavity. Look in the
angle of the lids near the inner "corner" of the eye
for the opening of this duct. If this duct is stopped
up the moisture trickles out on the face beside the
nose. A surgeon can usually open the duct again
without difficulty.

The skin is continuous over the eye. The part
lining the lid and folded over the eyeball is called
the conjunctiva. It is very thin and sensitive. If
a particle of grit gets into the eye so as to produce
irritation, and the tears do not readily wash it out,
the lids should be raised or the upper lid turned
back and the particle removed with a *clean* cloth
or absorbent cotton. A burnt match from which
the excess of charcoal has been rubbed off is an
excellent instrument for removing particles from

the eye; it is soft and sterile. The upper lid can easily be turned back by pulling up gently on the lashes while pressing with a pencil on the thin skin behind the stiff border of the lid.

A row of oil glands borders the lid, the secretion from which makes a barrier to prevent the moisture running over. A stye is an inflammation, often with pus formation, of one of these oil glands.

1. If some object flashes toward your eye what do the lids do? What is one of their functions?

2. Another use of the lid is to keep the eye moist. Hold your eyes open as long as you can. When the surface of the eye begins to get dry, a reflex nerve current compels the lid muscles to close the eye, moistening the surface. How often does this occur?

3. The tear gland is located under the upper lid. When dust gets into the eye, what function have the tears?

4. In what part of the eye does the dust collect?

5. How is the eye somewhat protected from blows of large objects?

6. What protects it from dust?

Blindness. Blindness is sometimes caused by derangement of the brain, sometimes of the nerve, sometimes of the lens, and sometimes of other parts. Some cases can be relieved by an operation, and some not at all. One of the most common causes of blindness is a contagious disease. The germs easily grow in the moist eye and produce an inflammation that may destroy the organ. Prompt treatment usually relieves the trouble; neglect is

dangerous. New-born babes are so often affected
by these germs that their eyes should be washed
daily with an antiseptic. In Egypt the house fly
carries the germs and sore eyes are endemic.

Care of the eyes. The eye is a very delicate
instrument. With only ordinary care it does fairly
well for people engaged in open, coarse occupations,
but for those whose work requires continued close
adjustment the eye needs especial care, and even
then often proves deficient. The light by which
we read should be adequate, but not very bright
like the direct rays of the sun. It should come
from above or from one side, so as not to shine
into the eyes or reflect from the page into them.
Most school rooms are so arranged that the light
comes from above or from the left, that the shadow
of the right hand in writing may be out of the way.
For reading, the light may well come from the
right side. The page should be uniformly illumi-
nated; cross lights with their shadows are to be
avoided. If the eye is directed to one object a long
time continuously, the focusing muscles become
tired. Frequent glances from the page to some dis-
tant object rest them. The distance at which a
book is held is important. Twelve to fifteen inches
is the best distance for steady reading, and we
should take care not to vary much from it.

The eyes are injured by dust, and should be pro-
tected from it as much as possible. The germs in

the dust are especially harmful. Inflamed eyes, with pus collecting in the corners, means germ infection. If the inflamed eyes are washed with a saturated solution of boracic acid, they usually recover quickly. Occasionally eyes are infected with virulent disease germs. Then they need the prompt attention of a physician and the use of a more potent antiseptic. Rubbing the eyes is one way of getting germs into them. The public towel or any other germ carrier is to be avoided.

Defective vision is a very common, perhaps the most common, cause of headache. The strain of trying to see when one cannot see clearly causes the pain. The trouble is relieved by wearing suitable glasses. If one suffers from chronic headache, it pays to have the eyes examined by a competent oculist. Glasses should always be worn when they are needed.

B. The Ear

Sound is caused by the vibration of the air. The vibration waves are caught by the external ear and conducted to the drum, a thin membrane which vibrates when struck by the sound waves. A chain of three bones carries the vibration to the internal ear, where it is translated to nerve currents and sent to the brain.

The external ear. There is no apparent reason for the external ear having just the shape it has. So far as we can see, it would do its work just as

well if it were regular and less wrinkled. At the entrance to the ear canal, especially noticeable in men, are many short stiff hairs which retard the entrance of insects The wax, produced by modified sebaceous glands, is also an impediment to insects. If it is necessary to remove the wax, it should be done with a smooth, blunt instrument, care being taken not to scrape and irritate the tender skin and not to reach to the drum. Sometimes
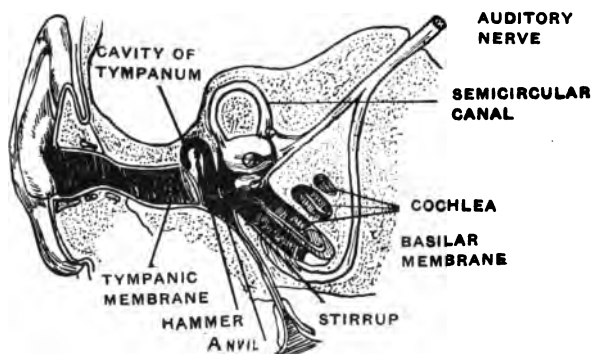
FIG. 63. Section of the ear.

the wax becomes hard and incrusts the drum, impairing the hearing. It can be removed by the use of warm soap suds and a syringe, but it is a rather delicate matter, and calls for the services of a physician.

The middle ear. The air chamber lying between the drum membrane and the internal ear is the middle ear. The Eustachian tube connects it with the pharynx. Thus the air of the middle ear is con-

tinuous with the atmosphere, and the pressure on both sides of the drum membrane is made the same. The lining of the middle ear and Eustachian tube is a mucous membrane continuous with that of the pharynx. When the latter is inflamed and germ-infected, the infection is likely to spread to the ears. A serious earache often results from a bad cold. The fluid formed frequently breaks through the drum and discharges into the canal. This may be harmless, but often it injures the hearing. Sometimes this discharge through the broken drum is the means by which pus germs get into the middle ear. The pus may burrow into the porous bone surrounding the middle and internal ear, and may reach even the membranes surrounding the brain and cause severe illness or death. A running ear should never be picked. It should be washed with sterile water only, and kept plugged with absorbent cotton. Every precaution should be taken to prevent infection.

The bones of the middle ear are called the hammer, anvil and stirrup. The first is fastened to the drum, and vibrates with it. The second communicates the vibration to the third, which is fastened to a membrane filling a "window" of the internal ear.

The internal ear. The form of the internal ear is that of an irregular sack. From it branch three semi-circular canals lying in three planes, perpen-

dicular to each other, and a "snail shell" (cochlea).
All are hollow and filled with a watery fluid. This
fluid touches one side of the membrane at the end
of the bone chain, and thus receives the vibrations
communicated from the air. In the cochlea is a
vibrating membrane, wider near the base of the
cochlea and narrower near the apex. This vibrates
in harmony with the vibrations which reach the
ear, the narrower parts of the membrane with the
higher pitches, the wider parts with the lower. The
auditory nerves terminate in special cells of this
membrane. The vibration of the membrane sends
nerve currents to the brain. Having a great num-
ber of widths of membrane, each vibrating to its
own pitch, we are able to distinguish between
pitches. We are unable to hear vibrations that are
either above or below the range of our membrane,
but training will extend this range. Probably other
animals may hear what we cannot.

The semi-circular canals are not for hearing,
but aid in maintaining the equilibrium of the body.
Since the canals lie in three perpendicular planes,
tipping the body in any direction alters the position
of at least two of the canals. Stand erect, look
straight before you a moment, then close your
eyes. Can you stand steadier with your eyes open
or closed? If the body begins to move, the change
in the relative position of objects is registered by
the eyes, and an unconscious muscular contraction

is made to restore the body to its erect position.
When the eyes are closed, we depend on the semi-
circular canals to recognize the tipping of the body
and to call for the muscular contraction needed to
restore the position. Standing steady is an uncon-
scious process, controlled probably by the cere-
bellum.

People who are deaf because of some affection
of the external or middle ear, can still hear if the
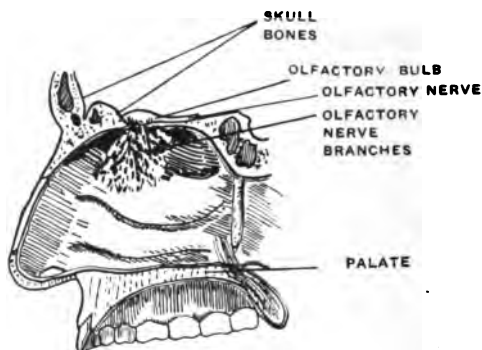
FIG. 64. Section of the nose cavity, showing nerves of smell.

internal ear can get the vibrations. If a thin piece
of wood shaped like a fan is held against the upper
teeth, the instrument catches the atmospheric
vibrations and conducts them through the teeth
and bones of the skull to the internal ear.

C. Smell

Observe over what part of the nasal cavity the
nerves of smell spread (see Fig. 64). They end in

olfactory cells which are exposed in the surface of the mucous membrane. Other cells of the membrane secrete a fluid which keeps the surface moist. A substance is smelled when minute particles of it floating in the air are brought in contact with the olfactory cells. How small a quantity of anything is required to affect the organ of smell is illustrated by the fact that we can smell a perfume which is
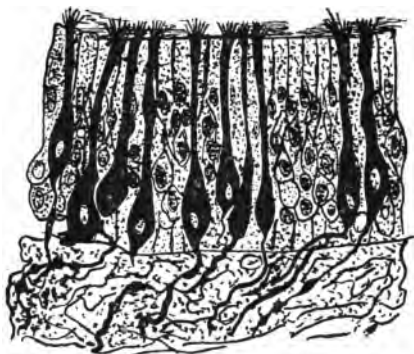
FIG. 65. Section of the mucous membrane of the nose, much enlarged, showing olfactory cells with hair-like projections.

kept in a tight-stoppered bottle. Sniffing simply increases the number of particles that strike against the mucous membrane of the nose. If you smell an odor constantly for an hour or so, is it stronger or fainter than at first? This means that some part of the smelling apparatus becomes exhausted and less active. While you are exhausted to one odor, are you sensitive to others, or does the exhaustion to one include all? A short rest (separation from

the odor) restores the acuteness of the sense to the exhausting odor.

The sense of smell is useful in helping us distinguish substances when we have once learned their odor. Thus we are able sometimes to reject unfit food, and the odor of good food stimulates the digestive organs. Smell is impaired by inflammation of the mucous membrane, as in a cold or in catarrh. Smoking injures the nasal membrane, and snuff-taking is especially harmful.

D. Taste

Taste is even more limited in its use than smell. When we get beyond the age of infancy, we are reluctant to put into the mouth to taste, things that are repulsive or unclean. Yet we do test them by smell. The flavor of foods is largely a matter of smell. The odor-giving particles rise from the mouth to the nasal chamber through the pharynx. If the nose is held during eating so as to prevent air currents from the pharynx from coming out, we lose most of the flavor of such things as onions and spices. There are four primary tastes—sweet, sour, bitter and salt. The hundreds of flavors are compounds of these and of odors.

Taste cells are situated in taste buds, which are in papillae scattered over the upper surface and sides of the tongue, and parts of the soft palate and pharynx. (See Fig. 66.) Short filaments from the

taste cells protrude through the opening of the bud
and come in contact with the food tasted.

1. Does the bud contain any other cells than the taste
cells?

2. Do any of the nerves that carry the currents from
the taste cells to the brain arise outside the taste bud?

3. Wipe the tongue dry with a clean cloth and place on
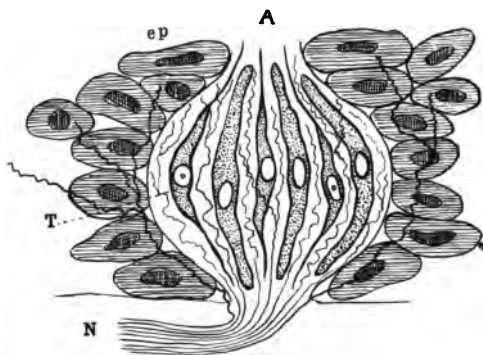
FIG. 66. Section through a taste bud. A—opening of bud, N—
nerve, T—taste cell, ep—cells of the mucous membrane.

it a few grains of sugar. Can you taste the sugar before
the tongue has again become moist?

4. Try the same with salt.

5. Can substances be tasted in the solid form? Or in
solution only?

6. In a spoonful of water dissolve as much sugar as
you can. With a clean wooden toothpick put a drop of
this solution on the back part of the tongue. After you
have perceived the taste, rinse out the mouth and put a
drop of the solution on the front part of the tongue. Is
the taste the same in quality and strength at both places?

7. Try the same experiment with salt, with a drop of lemon juice or vinegar, and last with some bitter substance, as a very weak solution of quinine.

8. Is the tip of the tongue more sensitive than the back to all tastes?

9. You might find it interesting to extend these experiments, comparing the right side of the tongue with the left, the edge with the middle of the top, etc.

10. Mix together two of the substances, as sugar and lemon juice, and test with the mixture. Do you taste both substances or only one? Try with different quantities of sugar. Does the sweet taste or the sour prevail?

With practice, taste becomes more discriminating. "Tasters" can distinguish in the qualities of teas differences so slight as to escape the untrained sense. It is probably the brain rather than the sense organ that is made more acute by practice. To the tongue accustomed to "hot" things like red pepper and Worcestershire sauce, mild flavors seem insipid and are unappreciated. Therefore, strong spices should be used sparingly.

E. Touch

In some of the papillae of the skin (Fig. 57) are touch corpuscles, in which nerves of touch end. When anything comes in contact with the epidermis, the corpuscle is pressed and sends a nerve current to the nerve center—spinal cord or brain. Some touch nerves end in cells in the deeper part of the epidermis. If the nerve endings are close

together, the sense of touch is keen; if they are far apart, the sense is dull.

To test the acuteness of the sense, take a pair of dull-pointed drawing compasses and set the points one-eighth of an inch apart. Have your neighbor hold out his hand without looking at it. Touch the palm with one point of the compass and ask him if he feels one point or two. Then touch with two points and ask the same question. If he feels the points as two, close the compass gradually as you repeat the test till you find the least separation that can be felt as two points. Repeat the experiments for various places on the hand, arm, neck and face.

1. What is the least distance at which the points can be felt as two?

2. What place is most sensitive?

3. What place do you find least sensitive?

4. What is the distance between compass points there?

5. When your hands are very cold are they more or less sensitive than when they are warm?

F. Temperature

There are irregular areas all over the body which, when touched with a cold object, give us the sensation of cold. There are other adjacent areas which, when touched with a warm object, give the sensation of warmth. Other areas are neutral. Since the warm areas and cold areas are distinct, they must be supplied by separate nerves,

but the nerves of one cannot be distinguished from
those of the other, and both seem to be like the
touch nerves that end in epidermal cells. Some
corpuscles lying deep in the dermis, having nerves
ending in them, have been supposed to function in
temperature sensation.

INFECTIOUS DISEASES

In studying the second chapter, you learned what germs are and how they are studied. Now you are to learn how they attack the body, why they cause disease, and how we oppose them.

Where germs grow. Some disease germs are, in the body, strictly limited to certain parts, while others are found in several places. Diphtheria germs grow in the mucous membrane of the air passage, chiefly the pharynx and larynx, and are rarely found in any other part of the body. Tetanus (lockjaw) bacteria grow in wounds, and, though they have excellent opportunity to spread through the lymph and blood channels, they do not do so. The bacillus of tuberculosis grows in any part of the body. It is found most frequently in the lungs because it comes in with the inhaled air. Malaria germs are in the blood, especially in the red corpuscles. Pneumococcus in the lung causes pneumonia, but it can flourish in other places, as in the membranes covering the brain, where it causes one form of meningitis. The smallpox germ seems to be distributed by the blood through the body, but develops pustules in the skin. Typhoid

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germs begin their growth in the mucous mem-
brane of the intestine, but in time spread through-
out the body.

How germs do harm. It has been proved that
many disease-causing microbes produce poisons
called toxins, and it is thought that all do. Each
kind of germ has its own toxin, differing from
every other. Sometimes these toxins are soluble,
and are therefore taken up by the lymph and
passed into the general circulation, as with tetanus
and diphtheria. The insoluble toxins are retained
within the germ till it dies, when they enter into
the circulating fluids and spread through the body,
poisoning the tissues. The virulence of a toxin is
illustrated by the fact that the toxin produced by
the tetanus germs growing in one small wound is
sufficient to produce death. Luckily, not many of
the toxins are so deadly as this. Many germs
cause the tissue in which they grow to break down
rapidly; others produce ulcers that endure for
months or years. Some germs cause the tissues in
which they grow to enlarge and harden, forming
tumors. Still other destructive work of various
kinds is done either by the germs directly or by
their products.

How the body combats germs. It is a fortunate
thing that not all the germs that get into our bodies
are able to grow there. In the air of our houses
and streets are myriads of microbes, scores of

which we inhale every minute. Many of these are
disease germs of various kinds. When they get into
the body they meet difficulties. The body does not
passively suffer the injuries done by disease
microbes. There are in the blood substances that
destroy germs, perhaps a separate substance for
each kind of germ, and that which kills one kind
has no effect on another. In the blood of some
people these germicide substances are sufficient to
kill the disease germs that get into the body.
These people rarely have infectious diseases. Peo-
ple in whom the germicidal substances are scanty
or absent are subject to diseases.

More important than the germicidal substances,
in the estimation of many physicians, is the power
of the colorless blood corpuscles to destroy germs.
(See page 83.) The different kinds of white cor-
puscles differ from each other in their power of
ingesting germs, some taking readily certain spe-
cies of bacteria, and others taking other species.
If the white corpuscles in one's body are active
germ destroyers, he is less likely to take an infec-
tious disease, and he recovers more easily if he does
catch it. A few years ago the discovery was made
that germs are not at all times equally acceptable
to the corpuscles. The difference is not in the cor-
puscle nor in the germ, but in the fluid that sur-
rounds the germ. There are supposed to be certain
substances in the blood, called opsonins, that make

the germs "taste good" to the corpuscles. If these "good tasters" are present the corpuscles take in the germs rapidly; if they are not present the corpuscles do little work. To stimulate the body to produce "good tasters," injections of serums and vaccines are sometimes used. The latter consist of dead bacteria of the kind that causes the disease. They are injected in quantities of 50,000,000 to 100,000,000 or more at one time, and the dose may be repeated. A serum is obtained from the blood of an animal, usually a horse, into whose body has been injected the dead or weakened germs or the toxin of the disease to be cured.

A third defense of the body against the injury of an infectious disease is antitoxin. This is a substance produced in the body to counteract the toxin of the disease. Antitoxin combines with the toxin and renders it harmless. It is thought not to destroy the germs but only their toxins. The white corpuscles then take care of the germs. Each disease has its own specific antitoxin. The presence of the toxin in the blood stimulates the production of the antitoxin. If the body responds slowly to this stimulus, the toxin may do its fatal work before the antitoxin has been produced to check it. If the antitoxin is produced quickly and abundantly, the toxin is destroyed and the disease is soon over. The quick supply of sufficient antitoxin is the requisite for prompt recovery. The

solution of this problem is one of the great achievements of modern medicine. Diphtheria antitoxin may be taken as an example. It is obtained from the blood of a horse. Into the body of this animal is injected, in measured quantities, diphtheria toxin (free from live germs) produced by cultivating the bacteria in blood serum in the laboratory. The horse's blood produces an antitoxin to counteract the toxin. After about a week another larger dose of toxin is given the horse and the body produces more antitoxin to meet the increased poison. This procedure is kept up for several months, till the horse's blood is well loaded with antitoxin. Then the animal is bled and from the blood antitoxin is extracted to be injected into the body of a person who has diphtheria. In nearly all cases in which it is used early it works a magical cure. It is given, also, to children who have been exposed to the infection and have not yet become sick, and it usually prevents the disease.

In this section you learn that the body may be helped in its warfare against germs by three substances—antitoxins, vaccines or dead germs, and antibacterial or germicidal substances—introduced from without. Some serums have only one function, as antitoxin; some may contain a germicidal substance and at the same time stimulate the production of "good tasters." The study of this subject is only in its infancy. Every year adds to our

knowledge of the principles that underlie it and to their practical application in remedy and prevention.

Incubation. The time that elapses between exposure to the infectious disease and the first symptoms of the sickness is called the incubation period. During it the germs are growing but have not become sufficiently numerous or produced toxin enough to cause noticeable effects. If the toxins are insoluble they are not set free in the body till the germs die and go to pieces, which may be many days after they make their incursion. Rabies (hydrophobia) has a long incubation, commonly more than a month and sometimes considerably more than a year. The period of measles is nine days, of German measles three weeks, scarlet fever two to four days, diphtheria one to five days, typhoid fever two weeks, chicken pox ten to fifteen days, smallpox nine to fifteen days, and whooping cough about two weeks.

Duration. The germs of a few infectious diseases, as leprosy and tuberculosis, may continue to grow in the body for years, but most diseases run their course in a short time. Pneumonia reaches its climax in about eight days, typhoid fever runs about four weeks. The disease is terminated when the opposing forces of the body have overcome the germs. If the germs are victorious in the contest, their toxin accumulates in sufficient quantity to

cause death within a certain time. Cholera is some-
times fatal within a few hours, commonly within a
day or two.

Recurrence. It is not altogether clear why we
do not commonly have certain diseases, as mumps,
measles and smallpox, a second time, while others,
as pneumonia and scarlet fever, may afflict a person
several times. Perhaps in some diseases there
remains in the body an antitoxin or other substance
that prevents the growth of the germs. It is prob-
able that every infectious disease is followed by a
period of immunity lasting, however, in some cases
only a few days or weeks, while in other cases it
lasts for months or years. The immunity lasts as
long as the antibodies,—germicides, antitoxins, or
whatever they may be,—remain in the body. They
are in time eliminated with the excretions. The
products of the germs of one disease sometimes
prevent the occurrence of a different but allied
disease.

Vaccination. The practice of vaccination de-
pends on the fact last mentioned. It was noticed
years ago in England that milkmaids who had once
been infected from certain sores on cows were
immune to smallpox. Dr. Jenner then introduced
the practice of inoculating well people with the
virus from the diseased cows, giving them the
cowpox, that they might be protected from the
dread disease smallpox. This practice of vaccina-

tion was followed in a crude manner for many years. Virus was taken from one person to inoculate another, and occasionally unintended germs were in the virus and horrible diseases were communicated. Now the vaccination is performed with great care and such disasters very rarely occur. A virus carefully prepared is used to inoculate a young cow that is in perfect health. The virus "takes" and produces sore spots full of pus. This pus, preserved in glass tubes, is the virus with which our arms are vaccinated. The exact nature of the germ in the virus has never been learned. The vaccine grows in our bodies, we have this mild disease, which prevents our having smallpox. The protection usually lasts several years, but the vaccination should be repeated occasionally, especially if there is smallpox in the community. The vaccination may not take if the virus is not fresh, or if the body is in condition to resist its growth. In the latter case, the body would probably resist smallpox, so we are protected.

Rabies. Very similar to vaccination for the prevention of smallpox is the practice of inoculation to prevent the development of rabies (hydrophobia). In this case the germs of rabies are cultivated in the bodies of rabbits, and the germs are weakened by drying the brain and spinal cord. The inoculation of a bit of this infected substance is made only in people who have been bitten by a

dog or other animal suffering from the disease. The weakened germs, introduced in large numbers and repeated doses in increasing strength, develop more rapidly than the virus of the rabies and prevent that disease by stimulating the production of antibodies.

A dog that froths at the mouth, acts strangely, and has bitten people should, if possible, be confined instead of immediately killed. If he is carefully kept a few days, his condition can be studied to see whether he has rabies or not. The trouble usually proves insignificant and the people bitten are freed from apprehension. If the dog is killed at once, his victims do not know whether they have been inoculated with rabies or not, and they either live in dread of the disease or they incur the expense of the preventive treatment, sometimes going hundreds of miles to a Pasteur Institute. If the dog is killed, his head should be cut off and sent to an expert, for examination of the dog's brain will determine whether he had rabies. The Pasteur treatment has recently been so improved and the appliances so perfected that the virus used can be sent by mail to any part of the country and administered by a local physician. The patient can thus live at home and keep on with his regular work while taking the treatment.

Diphtheria. Diphtheria is produced by a bacillus which usually appears first on the tonsils as a

white spot. For a day or two it is difficult to dis-
tinguish from tonsilitis, therefore cultures on blood
serum are made from the spot. If the diphtheria
bacillus is present, the cultures should show it in a
few hours. Children with questionable spots in
their throats are kept in quarantine till the diag-
nosis is certain. The diphtheria bacilli form a
membrane which may cover any part of the
pharynx and spread into the larynx or even the
trachea. The germs are confined to this surface
growth, but their soluble toxin is taken up by the
lymph and distributed through the body. The
membrane itself may become so large as to stop
up the air passage and cause suffocation, but the
passage can sometimes be kept open artificially.
The toxin is the greatest danger, poisoning the
nerve centers, especially those that control the
heart. If the artificial antitoxin is not introduced,
the toxin is likely to cause death before the body
can produce a sufficient quantity of antitoxin to
counteract it.

Tetanus. Tetanus, or lockjaw, is caused by
germs which are found in the soil of certain places.
They can grow in the digestive tract of the horse,
cow and sheep, and so become scattered in pastures
and barnyards, spreading the infection among ani-
mals and providing a supply for a human wound.
The germs seem to do no injury in the digestive
tract. Their toxin is probably destroyed by the

digestive ferments. But, introduced into the skin of the horse or other animal, they may work serious or fatal injury. The microbes get into the body through wounds that do not bleed much—as rusty nail pricks. The toy pistol is especially dangerous, since there are often tetanus germs in the dirt on boys' hands, and particles of the exploding cap sometimes penetrate the skin, carrying in germs with them. Like diphtheria, tetanus is successfully treated with an antitoxin obtained from the blood of a horse that has been made immune by doses of the toxin.

Tuberculosis. One-seventh of all the deaths in America and Europe· are caused by tuberculosis. The bacillus which produces the disease is easily recognized because it takes a peculiar stain when prepared for study under the microscope. It grows in almost any part of the body, most often in the lungs; then the disease is commonly called consumption. As it grows it destroys the tissues of the body and produces small lumps or tubercles, from which it gets its name. The progress of the disease varies a great deal in different persons; some live many years without seeming to get much worse, others succumb within a few months. Many people recover from the disease without difficulty. Even when seriously sick, the sufferer usually feels so hopeful of getting well that he neglects to take the means necessary to a cure. Tuberculosis is

one of the diseases successfully treated with a
serum.   But the most important treatment is
plenty of nourishing food and fresh air. A climate
in which the patient can remain out of doors day
and night, the year round, is often sought; and
even in cold climates the patients sleep out of doors,
warmly wrapped up.

Tuberculous people are everywhere, in houses,
shops and streets. The germs growing in their
lungs are thrown out in expectoration. They dry
up and blow about in the dust. We inhale them
and are so exposed almost daily to the infection.
If people suffering from the disease would be care-
ful of their expectorations, never spitting on floors
or streets, we should be much less exposed to the
germs.

This most fatal of all diseases, well known as an
infectious disease, is only recently recognized as
such by law. People having measles, smallpox, or
scarlet fever are not allowed to spread the infec-
tion, but there are in most states no laws ade-
quately guarding against the spread of tuberculosis.

Many people have thought the disease to be
hereditary, and some color is given to the supposi-
tion by the fact that tuberculous parents often have .
tuberculous children and grandchildren. The chil-
dren do not usually inherit the disease; but if par-
ents are diseased the children are usually weak,
and being daily exposed to the bacilli, often con-

tract the disease. Moreover, some people are especially susceptible to the disease, and this susceptibility is likely to run in the family. Many people advocate a law forbidding the marriage of men and women suffering from tuberculosis. A conscientious person who has the disease and who understands its power to injure the lives of others will not marry, and will exercise every care to prevent the spread of the germs in any way.

Other animals than man are subject to tuberculosis. It is quickly fatal to monkeys. Cows may have the disease a long time without its being noticed, and people have feared that their milk might spread the disease among men. Humans do contract bovine tuberculosis, but whether the disease may be transmitted by the milk has been much disputed. Cities that are most careful of their milk supply are requiring the animals that provide it to be free from tuberculosis.

This plague is most rampant in the crowded city tenements occupied by factory workers. Workers at confined and dusty trades are especially susceptible. The air they breathe is laden with germs and poisonous exhalations, their chests are cramped and weak, their wage is so small that they are often insufficiently fed. The feeble fall easy victims to this plague. The tenement sleeping rooms are dark, crowded and ill-ventilated. The germs of the disease are killed by sunshine, but in the dark and

dirty nooks of the tenement they live many months, bringing death to old and young.

The disease is preventable, and if we lived rationally, it would almost disappear in a generation. We should have to live in light, clean, airy dwellings, spend a good deal of time out of doors, and have plenty of wholesome food.

Medicines. Aside from the antitoxins and bactericidal serums, there are only a few drugs known that will cure any infectious disease. The attending physician may give medicines to accomplish various desired ends—to move the bowels, to stimulate the heart, or to act as a sedative; but the cure, the destruction of the germs, must come from the body itself. The emulsions given for tuberculosis are fat foods, not drugs. When you find anyone advertising to cure, by a process or drug known to him alone, any disease whatever, you may be sure he is untrustworthy. The germs of an infectious disease can easily be killed by antiseptics, but so can the body. The problem is to find something that will poison the germs without harming their host. A few drugs have been discovered that can be tolerated by the body in sufficient quantity to destroy the germs. Quinine, given for malaria, is one of these. Germs whose growth is limited to the surface of the body can be reached by antiseptics. Many individual germs in a colony causing diphtheria, tonsilitis, or catarrh can be killed by an anti-

septic spray, but some of the germs penetrate the mucous membrane so deeply that they could be reached only by those poisons which would destroy the membrane. Germs on the skin, however, can sometimes be completely destroyed by an antiseptic. Ringworm, caused by a mould-like vegetable growth, can be completely cured by one or two applications of iodine, if the parasite has not become intrenched in the deep hair follicles of the scalp.

This chapter on infectious diseases has not accomplished its purpose unless it has helped you see that the cure of any disease lies mostly in the body itself. Sometimes the defenses of the body can be augmented by serums from other animals, and a few drugs can be used to advantage; but we are mainly dependent on the work of our own cells. Careful nursing and dieting is valuable in conserving the strength of the sick. Hygienic living every day is the best assurance of recovery from sickness. Those whose bodies are weakened by dissipation, overwork, bad air or insufficient food suffer most from infectious diseases.

DISEASE, DRUGS, AND DOCTORS

What disease is. We have learned in the foregoing chapters that all the cells of the body have certain life activities, such as motion, assimilation of food, oxidation, growth and repair. Besides these general activities each tissue has its special functions; some secrete, some contract, some send nerve currents and some store food. If the cells are performing their normal activities we are in health. Inability of any cells or organs to perform their functions is disease.

Cause of disease. Diseases are due to causes some of which are well understood and some are still unknown. It is very clear that if a part of the body never fully develops, as a shriveled arm or leg, it cannot do its normal work. An overgrowth or faulty structure may likewise interfere with the activities of parts of the body. Also an accident that destroys a portion of an organ impairs the working of that organ. Parasites, whether biting or crawling into the skin or living in the intestine or other parts of the body, sometimes interfere with the working of the organs they infest. But most diseases are caused by defects less conspicuous.

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Individual cells may be affected so that their func-
tion is impaired in ways revealed only by the micro-
scope, or sometimes not revealed by any known
means.   Yet the organ of which the cells are a
part may not show any noticeable imperfection.
Many poisons have such subtle effects.   Most of
the common diseases are caused by germs, which
produce poisons that either destroy tissues or so
affect the cells as to prevent their normal activities.

The treatment of a disease.   Disease must be
treated according to the nature of the defect in the
cells and the cause of the injury.   No disease can
be cured while the thing that produces it is still
present and working its harm.   This book can do
you no greater good than to teach you to treat the
body rationally, in sickness as well as in health.
All superstitions and old household remedies must
be called in question.   When put to the test of
reason and science most of them fail and must be
discarded.   No common report that a certain rem-
edy or course of treatment has cured a patient is
worth much consideration.   Common reporters are
not qualified to judge.   A remedy or treatment
should be accepted only when, by repeated
trials, in hundreds of carefully studied cases, it
has proved to the most thorough scientific ob-
servers its beneficial effects.   Make a list of as
many remedies for various diseases as you can
learn through your neighbors, and see how many

you can find a rational ground for using. Try to
find out in what way each is supposed to remedy
the particular defect of the disease. Of course a
remedy is not to be declared worthless just because
a school boy cannot see how it may be valuable;
but if you can find no one able to give a reasonable
ground for its use, its value is to be strongly
doubted. A lively skepticism is a good attitude of
mind for a student.

The cure of disease. Diseases are cured by re-
moving their causes. If a disease is caused by a
parasite, the parasite must be killed or driven away.
When the parasite is on the skin (as lice, the itch
mite, ringworm) kerosene, iodine or poisonous
ointment can be applied directly and the offender
destroyed. Worms in the intestine can be de-
stroyed and expelled by the use of certain poisonous
drugs. The difficulty about killing the parasites of
most germ diseases is that the drugs that destroy
the germs would also kill the patient. There are
only a few drugs known that can be taken in doses
sufficient to destroy the germs without harming
the patient. Among these are quinine, which kills
the malaria germs; and a compound of arsenic,
which destroys the germs of syphilis and of sleep-
ing sickness. Calomel and salol kill some germs
in the intestinal tract.

Since the white blood corpuscles destroy germs,
anything that increases their action will help cure

the disease. Vaccines or bacterines (see page 226) are used for this purpose. Germs injure the body by means of the toxins they produce. If the toxins could be rendered harmless, the germs would soon be destroyed by the white corpuscles. Antitoxin (see page 226) is used for this purpose in diphtheria and tetanus.

Deficiency in organs. Sometimes, although the cause of the failure of certain organs to perform their functions is not understood, the organs can be brought to do their work by certain treatment. For example, constipation (which means deficient secretion in the colonic mucous membrane and failure of the intestinal muscles to expel the feces) is relieved by medicines that stimulate the muscles and glands of the intestine. Massage of the abdomen also stimulates the organs to activity and will often relieve the trouble. If the heart is doing its work poorly, there are stimulating drugs that whip it up and make it beat more vigorously. If the digestive glands fail to produce sufficient digestive fluids, the deficiency can be made up by taking ferments extracted from the digestive organs of slaughtered animals. A failure of the thyroid gland can be likewise compensated by the use of an extract from the thyroid gland of a sheep.

Malformations. When the failure of certain organs to do their work is caused by interfering growths, as adenoids blocking up the respiratory

passage, a surgical operation will remove the ob-
struction.   Crooked limbs, cross eyes, cataract,
pressure on the brain, tumors and many other
structural defects can often be completely cured by
the skill of the surgeon.

Indirect effects.   Drugs and applications are
much used to produce results that are not cures.
The immediate relief of pain does not work a cure,
yet it is often an advantage.   It is sometimes
accomplished by drugs that benumb the nerves,
sometimes by hot applications, by ice, by elec-
tricity, or by counter-irritants.   Tissues that are
injured may be able to recover without any assist-
ance if they are kept quiet.   Certain drugs may be
used to check the activity of these or neighboring
tissues and so bring the needed rest.   If some organ
is congested, the unusual blood pressure may be
relieved by drawing the blood away to some other
place, by means of a counter-irritant or a blister.
On this principle a plaster is applied to the skin
to relieve a pain in the deeper tissues; the feet are
put in hot water to relieve headache.

No attempt is made in this chapter to give all the
purposes for which drugs or methods of treatment
are used.   We are merely trying to show that there
is a rational aim in every proper procedure.   Some
treatments are intended to cure the disease directly.
others are to relieve harmful symptoms, others to
establish conditions under which the body can work

its own cure. Unless the treatment of the disease
is rational, it is just as likely to be harmful as bene-
ficial. The obligation we feel to "do something"
for a sick person drives us to all sorts of ridiculous
actions. We should do only what we have a good
reason for doing, not whatever may be recom-
mended by those who know nothing of the func-
tions of the organs or of the physiological effects
of drugs or of methods of treatment.

Physicians. The skilled physician prepares him-
self for the rational treatment of disease by years
of study. It is our duty to put a sick person into
the hands of a physician and to obey his directions
scrupulously because he knows better than any one
else what should be done. But we should never
forget that there are doctors and doctors. Though
most physicians of good repute do the best they
can for their patients, there are thousands of incom-
petent practitioners and thousands of charlatans
who aim to get their patient's money by fair means
or by foul. It behooves one to select his physician
with the greatest care. The doctor who is most
genial or most active in society or runs about with
the most appearance of business may not be the
most competent scientist. Put your trust in the
physician whom his fellow practitioners trust.
They usually know which of their brethren have
had thorough scientific training and carry level
heads. There is one "doctor" always to be avoided

—he who professes to be able to cure what others cannot, who advertises himself, guarantees a sure cure or money back. The ethics of the profession forbids advertising, and all reputable practitioners observe the prohibition. No physician has any private drug or method unknown to the others. The ethics of the profession makes it obligatory on everyone to communicate to the others anything he may learn that will promote the health of mankind.

The scientific physician is of no "school"; that is, he does not limit his treatment by any preconceived theory of how diseases can be cured: He uses the methods that have stood the test of experience, and is ever open to any new method that can stand the severe trial put upon it. The great advancements in the treatment of disease made within the last few years have all been made by such scientific physicians. Knowing that the regular physicians are eager to adopt any new method of treatment just as soon as a fair trial has proved it valuable, we use very poor judgment when we run after a fakir who claims to work cures by some new or private discovery. The fact is that every "quack" produces a great number of "cures" and gets plenty of testimonials of his skill. Most diseases usually get well if they are not treated too badly. The doctor in attendance gets the credit, whether his treatment did good or harm. Many cases of disease depend on the state of the mind, .

and are cured by abolishing worry and fear, by establishing hygienic habits of eating, working and resting, and by leading the patient to think he is getting well. Such cases can be cured by faith healers, and quacks, and doctors of any school as well as by regular physicians. Furthermore, many testimonials are bald falsehoods or statements made by people too ignorant of the subject to know whether or not they are true. Even the best trained and most clear thinking physicians are none too able to meet the problem of sickness, and we are grievously at fault if we allow an incompetent pretender to take the place of the skilled scientist.

Patent medicines. Patent medicines are mixtures of drugs designed to be used, without the advice of a physician, by people who are, or imagine themselves to be sick. Such preparations are often supposed to be secret and to have virtues not possessed by the drugs used by regular physicians. The truth is that the constituents of these medicines are well known to the medical fraternity and many of them are in common use. The patent medicines may now and then produce good results, but they are harmful in many cases. People who use them are incompetent to apply them just when they might be useful and to judge of their effects. Many of them contain alcohol and other harmful drugs. The supposed beneficial effect is often only the exhilaration produced by the alcohol. They are

almost never used rationally; that is, with an understanding of the nature of the disease to be cured and of the power of the drug to accomplish the desired result. The habit of using drugs is exceedingly vicious. No one who appreciates the difference between the scientific treatment of disease and quackery will have anything to do with patent medicines.

In the same class with patent medicines are all sorts of patent and traditional appliances to be used without the physician's advice, such as magnetic belts, amber beads, charms and curative jewelry. They are usually harmless, but utterly useless and silly. They encourage superstition, and are very objectionable when they take the place of treatment that might be helpful.

Prevention. More important than the cure of diseases is their prevention. We spend many times as much money in treating diseases as in checking their spread. The more we spend in preventing, the less we should need to spend in cure. Therefore, it would be financially more economical for us to double or triple the sums spent in preventing disease, and thereby reduce many fold the cost of treatment, as well as lessen the suffering and death from sickness. The work of prevention may be classed under two heads,—personal hygiene and sanitation. Matters of personal hygiene are such as each individual can attend to with reference to

his own body. They have been discussed in each chapter of this book. Sanitation is concerned with matters that are generally beyond the control of individuals and must come under the care of the community organization. They include water sup- ply, sewage, pure food, quarantine, destruction of germs, etc. They are discussed in the next chapter.

SANITATION

The two chapters immediately preceding this treated infectious diseases from the standpoint of the individual case of sickness. This chapter discusses the subject from the social standpoint. We are here concerned with the fight against the spread of infectious diseases. We must learn how diseases are spread before we can understand the method of checking their communication. The first problem is divided into two parts:

(A) How Disease Germs Escape from the Sick

Digestive tract. In diseases of the digestive tract, the germs grow in large numbers in the intestine and are consequently discharged by the million with the excreta. The germs may lurk in some part of the digestive system, as in the gall bladder, and may contaminate the bowel discharges months after the patient has recovered from the disease. Some germs that are distributed by the blood are very likely to be excreted by the kidneys and discharged with the urine. The germs of local infections of the urinary organs are also thus discharged.

Respiratory passages. Germs that infest the respiratory tract are easily discharged from the nose and mouth, not in ordinary breathing, but in coughing, sneezing, spitting and blowing the nose. It has been found that after a sneeze or cough germs may remain floating in the air many minutes, and extending several feet away—practically contaminating all the air of a small room. It has been estimated that seven billion tuberculosis germs may be expectorated by a consumptive in one day. You see the reasonableness of an ordinance forbidding spitting on floors and sidewalks. The handkerchief of a person suffering from any respiratory infection, even such a mild form as a cold, should be carefully handled that the germs may not be spread about on the hands or clothing.

Skin. Diseases which have skin eruptions disseminate the germs from the pustules or scales of the skin. Germs of such diseases are pretty sure to get on the clothing. They brush off and blow off from the skin and are easily spread. There is no security near one sick with any of these diseases, therefore the need of scrupulous quarantine.

A few diseases are often communicated by the bite of insects. A mosquito sucks the blood of a person sick of malaria or of yellow fever; some time later the same insect, biting a healthy person, injects the germs into him and so spreads the disease. Fleas in like manner communicate the

bubonic plague, and the tse-tse fly in Africa the sleeping sickness.

(B) How Germs Enter the Body

Respiratory passages. Since germs are so easily thrown off into the air by the sick, or after being dried are blown about in dust, they find their most common entrance to the body in the respiratory passages. You have already learned how well adapted the respiratory tract is to keep germs from lodging in the lung—the crooked passage with moist walls which catch the germs, the cilia which sweep them back to the entrance. Though the great majority of germs are thus removed, a number, large enough to maintain a foothold and produce disease, often get into the air sacks, where they can grow more easily than on the ciliated membrane. Some germs do, however, lodge and grow in the bronchial tubes and trachea. The spongy tonsils and folds of the nose offer a place for the lodgment of germs and are frequently the seat of infection. The upper part of the nose cavity lies very close to the floor of the brain, and the nerves of smell are an avenue along which, it is thought, the germs of meningitis sometimes penetrate. We probably always harbor several kinds of germs in the nasal passages, some of which are capable of producing disease. These are lying in wait, ready to develop when the body becomes unfit

to resist them, through exposure, fatigue, lack of nourishment, or illness.

The digestive tract. Another easy avenue of entrance for disease germs is the digestive tract. The warm, moist mouth, with particles of food between the teeth, offers suitable conditions for microbe growth. About thirty kinds of germs have been found in the mouth, many of them capable of producing disease. A few kinds of harmless germs may grow in the healthy stomach, but the hydrochloric acid of the gastric juice is an antiseptic and most germs do not flourish where the juice is normal. Stomach infection usually means defective gastric juice. In the intestines, especially the latter part of the small intestine, and the whole of the large intestine, the conditions seem almost to invite germ growth. Besides the germs of typhoid, cholera, diarrhea and dysentery, which infest the intestinal tract, a number of others probably gain entrance here and spread through the body. The retention of the feces in the colon gives opportunity for the growth of germs of decay, whose toxins are absorbed, producing headache and fever. The bowels should be emptied at least once a day.

Besides the microscopic parasites, there are several worms that infest the digestive tract. Most of these are taken in with the food, and spend their life in the intestine, producing discomfort or severe

illness. Trichina penetrates the walls of the tract and spreads through the body, often with fatal results. The hookworm, which has produced such havoc in the West Indies and the Southern States, gains entrance to the body through the bare feet. In time it comes to the intestine, where thousands may hang fastened by little hooks. Well-known drugs will kill and remove most worms.

The skin. Some kinds of germs make their entrance to the body through breaks in the skin, as those of tetanus, rabies and blood poisoning. Malaria, bubonic plague, yellow fever and sleeping sickness are introduced by biting insects. Some pus-forming germs work down into the oil glands and a few into the sweat glands, producing pimples, boils and carbuncles. There are a few kinds of surface parasites, as ringworm, that grow in the epidermis, hair follicle and glands, and never penetrate below the skin. Wounds offer an easy avenue to a variety of germs that grow in the blood, but, so long as the skin is unbroken, it presents an almost perfect barrier to the ingress of the germs of severe disease. (See page 188.) It is important, then, that we avoid even trifling wounds, and that we keep cuts and scratches covered and clean. It is well to apply tincture of iodine or a solution of potassium permanganate or other effective antiseptics to even slight wounds. Boracic acid is too mild to be of much value in

such uses, and the frequently employed hydrogen peroxide is inefficient and decidedly objectionable in fresh wounds.

MEANS OF PREVENTION

Destroy germs. A bright light, sunshine, or a very strong artificial light kills most germs in a few hours. It is the dark tenements and not the well-lighted homes that harbor tuberculosis and other respiratory diseases. Desert air is wholesome, free from disease and decay, because nearly all the hours of daylight are hours of sunshine. Drying is also a potent factor in the destruction of germs. Many microbes produce spores that can withstand considerable drying, while others succumb easily. The most thorough means of killing germs is by heat. Ordinary cold temperatures do not kill germs; but no germs, not even spores, can long endure a boiling temperature. A dry heat above the boiling point is the best destroyer, though boiling water or boiling hot steam is effective. Boiling heat should be applied for about an hour; a higher temperature requires less time. Many poisons (antiseptics and disinfectants) are used to kill germs. Different poisons are suited to different uses. Mercury bichloride (corrosive sublimate) has been a favorite for washing surgeons' hands; carbolic acid and lysol for sterilizing thread and instruments. Alcohol, boracic acid, formalin

and lime are also common substances used for kill-
ing germs. Care must be taken that the poison
actually comes in contact with the microbes.

Disinfection. The discharges from the mouth,
nose, kidneys and bowels can be disinfected as an
important means of preventing the spread of infec-
tious diseases. Quick lime is a cheap and effective
agent for disinfecting dry privies and waterclosets.
It loses its strength by air-slacking, so it should be
used fresh, either dry or dissolved in water (milk
of lime). Lime destroys cloth and leather, and is
used only on that which is to be thrown away.
Burning is the best means of destroying sputum.
Lysol in the sputum cup is a good disinfectant.
Handkerchiefs containing infectious discharges
should be thoroughly soaked in an antiseptic or
boiled, before going to a common laundry. Wash
clothing can be disinfected by boiling, but other
fabrics can be more conveniently treated by
fumigation.

Fumigation. Destroying germs by fumes or
poisonous vapors is fumigation. Rooms are usually
fumigated, as are also fabrics that will not endure
washing. Formalin and burning sulphur are the
common agents employed. The room should be
tightly closed, the cracks of the windows and
doors covered with strips of paper or adhesive
plaster. The beds should be opened and the clothes
spread out loosely, that the fumes may penetrate

to every part. Formalin may be sprinkled on a
sheet to evaporate, or, better, introduced through
the keyhole as a vapor. The sulphur is lighted
after the arrangements are finished, and the oper-
ator quickly leaves the room and makes the door
cracks tight. The room should remain closed sev-
eral hours. Thorough fumigation destroys all dis-
ease germs and most vermin, but formalin fumes
do not kill bedbugs.

Quarantine. It is desirable that people suffering
from most infectious diseases be kept away from
other persons. We maintain a strict quarantine in
cases of diphtheria, smallpox, scarlet fever and
some other diseases. We are coming to be more
careful of pneumonia and meningitis. The germs
of influenza (grippe) and colds are already so wide-
spread that practically everyone is now exposed to
them. We have to resist them, not keep them
away from us. Moreover, these diseases are
usually so light that sufferers from them can attend
to their business and would resent the loss of
income that would result from quarantining them.
When we suffer from these diseases that are not
subject to quarantine, we should be especially care-
ful not to spread the germs by coughing or expec-
torating in public places; and in such diseases as
cholera and typhoid we should take the precaution
of disinfecting the excretions. A little care may
save many lives.

Biting insects. Cases of diseases of which the germs are carried by insects should be kept away from insects as much as possible. Patients suffering from malaria and yellow fever should be kept behind mosquito-tight screens. In Africa, the tse-tse fly infests the low lands along the water courses. If the people could remain in the upland, they would be free from the sleeping sickness. The extermination of obnoxious insects is an important means of safety. The bubonic plague is carried by a flea which infests rats and squirrels. Free a city from these animals, and you check the spread of the plague. The United States government and the local authorities of San Francisco combined their forces to that end, when the plague was recently introduced into that city. Scientists may well turn rat-catchers when by so doing they can save thousands of lives and millions of dollars, as was done in the successful campaign in San Francisco.

Mosquitoes lay their eggs on the water. The young (called wigglers) live in the water, coming to the surface to breathe—living most of the time at the surface with the breathing pore open to the air. When grown to full size, the wigglers go into a resting stage, during which time the body is transformed into the winged insect. Then the skin cracks open, the mosquito draws himself out of the empty shell floating at the surface of the water and

flies away. Since the wigglers cannot remain away
from the surface, they are easily destroyed by a
film of oil on the water. An exceedingly thin film
of oil is sufficient to get into their breathing pore
and cause death. The warfare against mosquitoes
consists in draining swamps, filling mudholes, and
sprinkling with cheap oil the standing water that
cannot be drained. In stamping out yellow fever
in New Orleans, it was found necessary for sanitary
inspectors to go from house to house, emptying the
receptacles for waste water, and compelling people
either to screen their barrels of water, or to put in
enough oil to cover the surface. Fine-meshed mos-
quito-bar, protecting both sick and well, is not only
a convenience but also a sanitary precaution.

Food. A large part of the infectious sickness
which we suffer could be prevented by greater care
of the food. Thorough cooking sterilizes food, but
"there's many a slip 'twixt cup and lip." After the
food leaves the stove, there is chance for it to
become contaminated before it reaches the mouth.
The dishes in which it is served may have been
washed in impure water, the cook sometimes has
an infectious disease, but the worst of all defilers
are the flies. If the flies get no chance to pick up
germs, they are merely filthy and annoying; but
when they can get to the germs they bring disease
with them. Raw vegetables—celery, radish, let-
tuce, cress and the like—may bring us the germs

from sewage used to fertilize the soil or from handling in the market.

Milk is easily contaminated, and is such good food for the germs that they increase rapidly in it. It is often so filled with germs as to be unfit for human food. Infants especially, whose chief food is milk and whose digestive tract is not accustomed to the fermentive and putrifying bacteria, suffer from bad milk. If milk is properly handled, the number of germs of souring and decay can be kept within a harmless limit, and the microbes of infectious diseases altogether excluded. Milk should be cooled within a few minutes after it is drawn from the cow, and kept cool until it is used. Of course cleanliness must be maintained always; bottling helps in this.

If we are not careful, we are likely to take in with our food, besides the germs of infectious diseases, the poisons of decay. Every large city has its corps of sanitary inspectors, one of whose duties is to go through the markets and see that no spoiled meat or decayed fruit is sold. The germs of decay produce poisons (called ptomaines) which may not be perceived by the buyer, but which may cause sickness and death. The worst ptomaines of meat are those produced by germs growing in the bodies of sick animals. It is best to exclude from the market the flesh of all sick animals.

Flies. One of the commonest germ-carriers is

the house fly. It eats germs and gets its feet covered with them. Then it visits the table, shaking the microbes off its feet and depositing in its specks the microbes that pass undigested through its intestines. Hundreds of germs can be left in this way by a single fly. The dining room and the kitchen should always be screened against flies. These pests should be scrupulously excluded from the sick room, also, lest they pick up the germs and carry them to other rooms and other houses. We should above all take pains to prevent the breeding of these insects. The fly lays her eggs in all sorts of filthy places—barnyard manure, garbage, dead rats, bones or scraps the dog leaves, etc. It takes about a week for the eggs to hatch and grow into mature insects. Garbage cans should be shut tight to exclude flies, but if they are emptied and thoroughly cleaned even once a week, they cannot breed flies. A little pains in keeping the premises free from filthy litter, and keeping the manure in a closed box and frequently carted away, will give relief from the fly pest.

Drinking water. The most common carrier of disease germs that infest the intestines of adults is drinking water. Water supplies are easily contaminated with sewage, and sewage is pretty sure to contain the germs of intestinal diseases. For small cities, artesian wells afford a safe supply of water, but such wells are possible only in certain districts.

They cannot supply water enough for a large city. The problem of water supply for cities is too great for discussion here. The individual is dependent on the community supply, but if this is bad he can protect himself by boiling the water or by using distilled or spring water privately supplied. In the country each family usually has its own well, which can be made to supply wholesome water, but often is a source of infection. The well curb should stand a little higher than the surrounding ground and be thoroughly cemented up, that no rain water can run in from the surface and no rats or other vermin gain entrance. Care should be taken in the location of the well that it is so situated that the water which seeps in to supply it does not come from barnyard, privy, or any impure source. You can not always tell by the taste or smell whether water is wholesome. There may be hundreds of germs in a glass of water that is clear and odorless.

Clean air. Clean air is more necessary to healthful living than we commonly think. Dust and germs are usually mixed in the dirty air of our streets and buildings. Rough boards covered by a nailed-down carpet make a very unhygienic floor. The floors should be smooth and tight, so dressed that they can be conveniently wiped with a damp or oily cloth that will pick up all dust. Rugs that can be removed to be dusted are the only suitable carpets. The vacuum cleaning process is to be

commended, because it removes all the dust it dis-
turbs; a broom fills the air with tiny particles from
the floor, which get into the cupboards, penetrate
the draperies and settle on the furniture. Street-
sprinkling makes the air not simply more pleasant
but also more hygienic. The oil dressings for
streets are to be particularly commended; they
hold the dust so well that they need no sprinkler
to make them muddy several times a day. City-
dwellers, filling their lungs with smoke every day,
seem to think that clean air is not possible in a
large community. Smoke is harmful to the lungs,
and a polluted atmosphere is not necessary to
either a commercial or a manufacturing center.
When our social conscience is more fully aroused,
we shall cease defiling the city air with smoke and
unwholesome odors.

   Light. One of the most important subjects of
public sanitation is light. We have seen that it is a
potent germ destroyer. The inadequate light of
tenements and factories is responsible for the ruin
of many eyes, and the resulting deficiency of work-
ers. In our own homes we can do something in
the cause of better light by throwing up the shades.
Better bleach the wall paper and furnishings than
shut out the wholesome sunshine. We ought to
build houses that will admit abundant light, fit them
with furnishings tolerant of light, and keep them
so clean that we shall not be ashamed to let in the

sunshine. The worst offenders against light are the tenements of the poor in large cities. Space is so valuable that rooms are small, stairs and passages are dark and narrow, and the open areas for light and air altogether too insufficient. The profits that come to the landlord from crowded tenements seem too great for him to resist. The remedy is in the strict enforcement of building ordinances which provide for plenty of light and air in every tenement room.

Noise. It seems to those who live in a quiet world that noise has nothing to do with health. To those, however, who live in a city full of noises and who suffer from nervous disorders, the soothing influence of quiet is appreciated. No one can tell how much the nervous equilibrium of well people is disturbed by noise. We ought to conserve all our energy for the needs of life, and to this end shut out unnecessary noises and nerve-racking offenses. The "zone of quiet" established around hospitals for their protection against disturbances might well be extended. We ought especially to guard our sleeping hours, that our quiet slumbers may bring the strength we need for the day's labors.

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